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An Intelligent Waste Management System Enabled by IoT

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Abstract*:* Waste management is an important aspect to be addressed in Smart Cities and buildings. An effective waste management system can reduce the reliance on workforce and also reduce the labor cost required for systematic waste collection. The advancement in IoT technology enables waste management to be carried out effectively and promptly when the garbage is fully occupied. This work aims to develop a smart waste management system based on the Internet of Things (IoT), implemented with sensors that can track the level of waste in the garbage bin. The developed idea here is novel, deploying a simple IoT enabled ultrasonic sensor setup to realize waste level monitoring and remotely making the data available to users so that waste collection can be carried out effectively and timely upon full occupancy.

Keywords: *Waste management system, waste monitoring, IoT, ultrasonic sensor*

1. Introduction

Waste management is an important issue, especially in developing countries where the waste is not effectively managed [1]. It is crucial to managing the waste because some of these wastes can be recycled. In the past, the waste management is labor-intensive. With the advancement of technology, especially with the development of Internet of Things (IoT) [2], it became a trend to deploy IoT technology in waste management so that smart features can be implemented in waste management systems [3-5]. The key benefits of having a smart waste management system are the reduced reliance on workforce and is therefore more cost effective.

A variety of smart waste management systems being introduced, leveraging on different technologies with controller boards such as Arduino Uno, Raspberry pi, and myRIO as the brain of the system, as well as infrared and ultrasonic sensors to detect objects and wastes [6-13]. Generally, these smart waste management systems are costly and complicated to implement, which defeat their purpose of being low cost, simple to set up and effective. In this paper, intelligent waste management was developed using a cheaper alternative, NodeMCU. NodeMCU is an ESP8266 based microcontroller with a built-in Wi-Fi module for internet connectivity, coupled with an ultrasonic sensor to monitor the level of trash in the garbage bin so that an immediate response can be conveyed to the waste administrator. As a result, the waste in the garbage bin can be cleaned up in time without constantly checking by the cleaner. Besides, in order to encourage the use of the smart waste system, the system is designed with an automated voice feature, which detects the approaching users.

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2. Method

The block diagram of the smart waste detection system is given in Figure 1. The HC-SR04 ultrasonic sensor is placed on the inner part of the garbage bin and facing the other wall of the garbage bin. The sensor is located at the maximum height of the garbage bin and is used to detect solid waste. When the rubbish in garbage bins is filling up, the distance detected by the ultrasonic sensor will decrease. This data from the sensor is sent to NodeMCU and through Wi-Fi connection, the NodeMCU is able to sends the information to the Blynk app on the user's mobile phone. The Blynk apps can be configured to display the level of trash in the garbage bin and notify the user when the garbage bin is full.

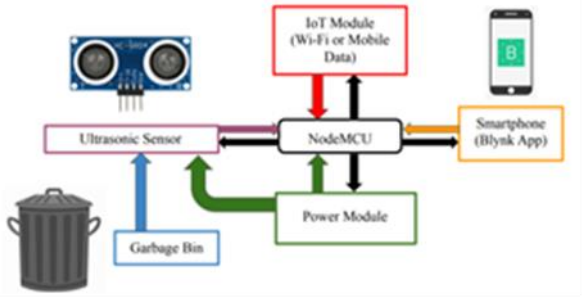

Fig. 1. The block diagram of the garbage detection system.

The block diagram of the automated voice and motion sensor system is given in Figure 2. Here, the HC-SR501 PIR sensor is located at the outer part of the garbage bin and facing up. This infrared sensor acts as a motion sensor and detects the presence of people who throw the trash into the garbage bin. The signal from the PIR sensor is then used to trigger the automated voice module and speaker via the NodeMCU. When the PIR sensor detects the motion of people plus additional trash is detected in the garbage bin, the speaker will produce a voice message to notify the person that the trash was collected.

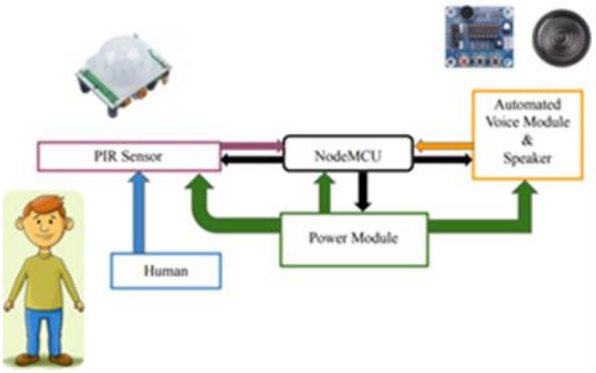

Fig 2. The block diagram of the automated voice and motion sensor system.

The system flowchart which describes the overall operation is illustrated in Figure 3. The flowchart shows the sequence in the system until the garbage is collected.

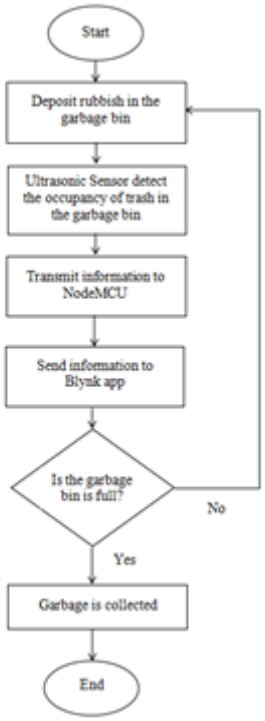

Fig. 3. The flowchart for the smart waste system.

The circuit connection for the smart waste system is shown in Figure 4. The HC-SR04 ultrasonic sensor is connected to the NodeMCU. The Vin pin of the NodeMCU is linked to the Vcc pin of the ultrasonic sensor, followed by connecting the ground pin of the ultrasonic sensor to the ground pin of the NodeMCU. Subsequently, the trigger and echo pins of the ultrasonic sensor are connected to the D1 and D2 pins of the NodeMCU, respectively. Prior to connecting all of these components, the CP2102 driver needs to be installed in the NodeMCU. The 9V battery is used as the power supply.

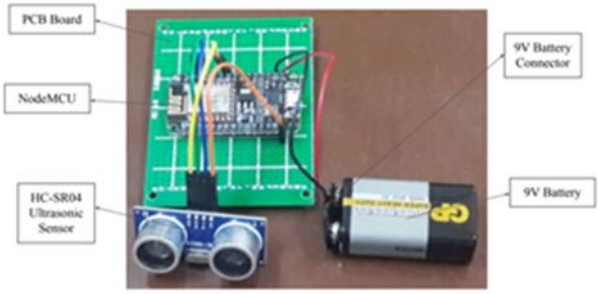

Fig. 4. The circuit connection of the detection system.

The circuit connection for the automated voice and motion sensor system is shown in Figure 5. The HC-SR501 PIR sensor and ISD1820 module are connected to the NodeMCU. To connect the PIR sensor and ISD1820 module to the NodeMCU, the Vcc pin of the PIR sensor is linked to the 3V3 pin of the NodeMCU, followed by connecting the ground pin of the PIR sensor to the NodeMCU's ground pin. The output pin of the PIR sensor is then connected to the Pepin of the ISD1820 module, while the Vcc pin of the ISD1820 module is linked to the 3V3 pin of the NodeMCU. Finally, to complete the connection, the ground pin of the ISD1820 module is linked to the ground pin of the NodeMCU. The 9V battery is used as the power supply.

In the following, the setup for the IoT for the smart waste system is described. The software used to code the smart garbage monitoring system is Arduino IDE software, as shown in Figure 6. In the first step, the following link is added to in the additional Boards Manager URLs: (http://arduino.esp8266.com/stable/package_esp8266com_index.json) and then click “Okay”. The step is shown in Figure 7. In the second step, “esp8266 by ESP8266 Community” is installed from the Boards Manager. This step is shown in Figure 8. For the final step, “Blynk” is installed from the Boards Manager as well, as shown in Figure 9.

This section describes the configuration of the app interface for the Smart Waste Monitoring System. The app that is used for the smart system is the Blynk app which is given in Figure 10. Two widgets are added, which are the gauge and notification widget. The gauge widget is can be configured to display the level of the trash that is detected by the ultrasonic sensor. Meanwhile, the notification widget is used to notify the user when the garbage bin is full. Consequently, the “Garbage Bin is full” message will pop out on the users’ smartphone after the bin is full. Both widgets in the Blynk app are shown in Figure 11.

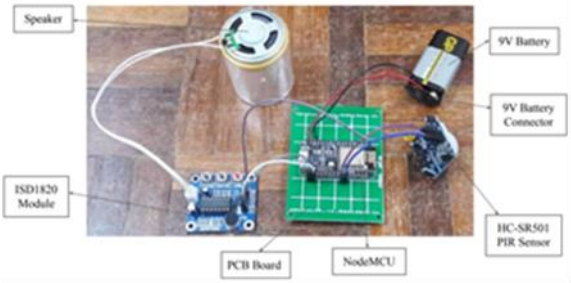

Fig. 5. The circuit connection of the automated voice and motion sensor system.

Fig 6. The Arduino IDE software.

Fig. 7. First step in Arduino IDE software.

Fig. 8. Second step in Arduino IDE software.

Fig. 9. Final step in Arduino IDE software.

Fig. 10. Blynk app.

Fig. 11. Widgets in the Blynk app.

3. Results and Discussion

In the following, the demonstration of the developed smart waste system prototype is presented. Prior to the functionalization, the widgets need to be set up in the Blynk app. For the smart system here, “gauge” and “notification” widgets are used in the Blynk app, which is shown in Figure 12. To detect the level of trash in the garbage bin, a few important lines of code is uploaded to the NodeMCU via the Arduino IDE software, as shown in Figure 13. This code is to set a certain distance between the ultrasonic sensor and the trash so that it will trigger a signal to the NodeMCU when a distance is achieved. The signal will then prompt Blynk app to alert the user when the garbage bin is full. Additional lines of IF statements can be added to the code to allow the Blynk app to show the amount of space left in the garbage bin before it is full.

All the components are placed inside the packaging hub, specially designed to house the IoT system and the sensor (Figure 14). A 9V battery is used as the power supply for the smart system. At first, when the garbage bin is empty, the Blynk app displays the distance that is detected by the ultrasonic sensor which is 22 cm (width of the bin). This indicates the distance between the ultrasonic sensor to the other wall of the garbage bin.

After the garbage bin started to be filled with trash, the Blynk app displays the distance that is detected by the ultrasonic sensor which is still 22 cm. This is because the ultrasonic sensor still does not detect the trash in the garbage bin. Therefore, the garbage bin is still considered as still not being occupied (see Figure 15).

Fig. 12. The widgets in the Blynk app.

```
if (distance <= 5){
  Blynk.notify("Garbage Bin is full");
  }
```

Fig. 13. The important lines in the coding for the Garbage Detection System.

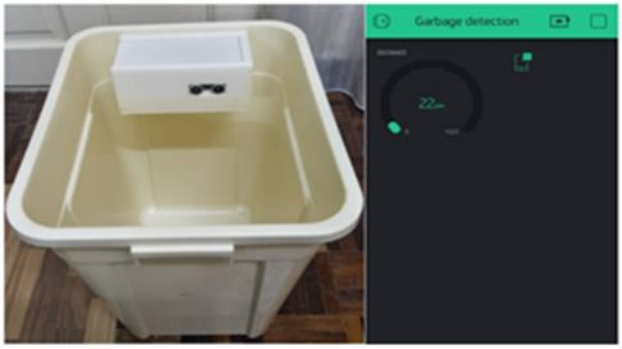

Fig. 14. The garbage bin is empty and the distance detected is displayed on the Blynk app.

Fig. 15. The garbage bin started to fill with trash and the distance detected is displayed on the Blynk app.

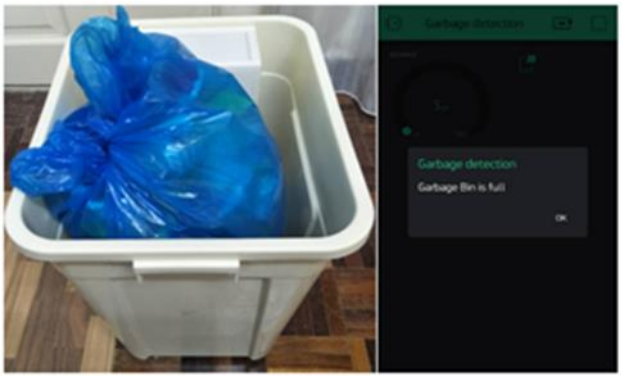

Fig. 16. The garbage bin is full and the notification is received on the Blynk app.

After the garbage bin is filled with another trash, the Blynk app displays the distance that is detected by the ultrasonic sensor which is 3 cm. The Blynk app automatically notifies that the garbage bin is full. This means that the garbage bin is already being occupied and ready to be emptied (see Figure 16).

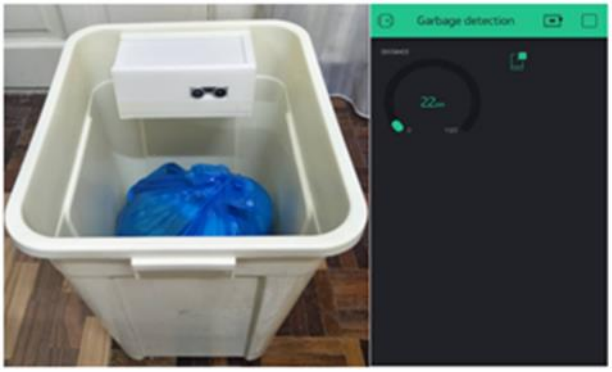

Fig. 17. The Automated Voice and Motion Sensor System installed to the garbage bin.

This section describes the implementation of the Automated Voice and Motion Sensor System. All the components were placed inside the packaging hub specially designed to house the automated voice system. As soon as the motion sensor detects the motion of people that throw the trash in the garbage bin, it responds by voicing “Welcome to the smart garbage bin. Thank you!!”. For this system, A 9V battery is used as the power supply for the system (see Figure 17).

4. Conclusion

The proposed IoT system for monitoring the occupancy of the waste in the garbage bin is able to perform its intended function. The readings obtained from the HC-SR04 ultrasonic sensor, which is an indicator of the waste level in the garbage bin, is observed through the mobile Blynk app. The data is analyzed using the gauge widget in the Blynk app. The Blynk app will notify the users of the waste occupancy level, and the users will be alerted to full waste occupancy in the bin. At the moment, the current setup is meant for non-organic waste. The current IoT enabled waste management system deploys the ultrasonic sensor to sense the waste occupancy level, which is meant for waste level detection, without the capability of sensing organic waste. The development here is potential for implementations in commercial premises such as shopping malls and offices, which are not necessarily created for organic waste. The concept here is novel, deploying a simple IoT enabled ultrasonic sensor setup to realize waste level monitoring and remotely making the data available to users via the Blynk app, so that waste collection can be carried out effectively and timely upon full occupancy.

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Author contributions

Fathin Izzaty Fahmi: Conceptualization, methodology, validation, formal analysis, investigation, writing—original draft preparation, visualization. **Kah-Yoong Chan:** Conceptualization, writing—review and editing, supervision, project administration, funding acquisition. **Chu-Liang Lee**: writing—review and editing, supervision. **Wai-Leong Pang:** writing—review and editing, supervision. **Gregory Soon How Thien:** writing—review and editing. **Zi-Neng Ng:** writing—review and editing

Conflicts of interest

The authors declare no conflicts of interest.

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