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IoT-based communal garbage monitoring system for smart cities

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ABSTRACT

In Malaysia, approximately 38,000 metric tons of garbage are generated due to human daily activities. This is due to the growing population in the urban area, hence increasing the tendency of overflowing garbage due to the insufficient space in the garbage container. In addition, the tight schedule of the garbage collection allows the spreading of the toxic odor as the garbage start to rotten up, hence leading to air pollution. Therefore, a systematic waste management system is important to provide a healthy and clean environment to the community. In this work, a communal garbage monitoring system has been developed to notify the administrator of the status of the container. Besides monitoring the level of garbage, the system is also designed to monitor the temperature, humidity, and air quality of the garbage container. These monitored data will be uploaded at the cloud for real-time monitoring. Compared to the other work, a real test-bed implementation has been conducted considering different types of waste including food waste, paper, bottles and metal; to determine the accuracy of the developed system. The results show that the system has high reliability and high accuracy with 96% for food waste and 98% for other types of waste.

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1. INTRODUCTION

A smart city refers to a city that integrates information and communication technologies (ICT) to improve the performance as well as the quality of public services including economy, governance, people, environment, mobility, security, and agriculture [1]. In short, a smart city aims to improve the quality of the human lifestyle through the implementation of ICT in daily life. According to the statistics given by National Environment Health Action Plan (NEHAP) in Malaysia, the total waste generated due to human activities in 2019 was 4.0 million tons [2]. The growing population especially in the urban area has increased the amount of garbage produced and therefore becoming one of the crucial problems in most countries around the world [3]. This is due to the increasing number of activities such as concerts and parades, and the tight schedule for the garbage collection in which has caused the overflowing of garbage in that urban area.

The overflowing of garbage leads to various problems for the health as well as the administration level. From a health point of view, the overflowing of garbage will lead to air and water pollution [4], [5]. When the overflowing garbage is exposed to the sun or high temperature, the toxic odor will be released by the garbage causing air pollution which will affect people especially those people who have respiratory problems. Besides, the overflowed garbage can also cause water pollution as the chemicals produced by the rotten waste will pollute the water which is not safe to be used. In addition, poor garbage management that causes the overflowing of the garbage will lead to the breeding of mosquitoes and other harmful insects which may endanger the community. From the administration's point of view, the overflowing of garbage affects the appearance of the city, thus giving a bad impression to the tourists hence affecting the economy of the tourism sector. Therefore, immediate action needs to be taken to ensure the level of cleanliness of the cities is good and therefore promotes good health.

The emerging of the internet of things (IoT) technology has accelerated the development of internet-based applications that provides advantages to the individual, community, and also industry. IoT is a physical device that is connected to the internet for control and monitoring. Many researches has explored the usage of IoT application that include studies in healthcare [6], smart cities, building management [7], [8], agriculture, and transportation [9]. Several researchers has focused on developing the garbage monitoring system that are intended for specific target applications. Table 1 shows the target applications, the types of sensors and the methods that has been used by several works on developing the garbage monitoring system.

Table 1. Summary of sensors and target applications for garbage monitoring system

References	Sensor	Target application	Method	Function
[10]-[20]	Ultrasonic sensor	Garbage level	Mounted on top of the garbage bin	Measure the level of garbage-filled in the garbage bin
[21], [22]	Temperature sensor	Bin status monitoring	Mounted on top of the bin's lid	Monitor the temperature inside the garbage bin
[22], [23]	Humidity sensor	Bin status monitoring	Mounted on top of the bin's lid	Monitor humidity of the garbage bin
[21], [24]	Gas sensor	Bin status monitoring	Mounted on top of the bin's lid	Monitor the gas concentration inside a garbage bin

Although many works have focused on developing the garbage monitoring system, to the best of our knowledge, the validation of the developed system has not been discussed clearly. In this work, a communal garbage monitoring system is developed to monitor the level of garbage, temperature, humidity, and concentration of gas in the garbage container. The accuracy of the developed system has been investigated through a test-bed implementation considering different types of garbage such as food waste, paper, bottles, and metal. Also, the developed system is integrated with the cloud for data monitoring and storage purposes. In addition, the system is designed to send a notification to the person in charge when the garbage container is full to avoid the spreading of toxic odor.

2. RESEARCH METHOD

In this work, an Arduino WeMos D1 equipped with the WiFi module is used as a controller. The WiFi module is selected as a communication interface between the IoT devices and the cloud. This is in line with the development of the smart city where the city will be covered with the Internet connection to support the IoT-based application. To monitor the level of temperature and humidity in the garbage container, the DHT22 temperature and humidity sensor are used. Note that, high temperature in the garbage container will cause the toxic odor to be released. Therefore, to avoid air pollution, the MQ-135 sensor is used to detect the presence of gas such as NH_3, NOx, alcohol, benzene, smoke, and CO_2. To determine the level of the garbage in the garbage container, an ultrasonic sensor has been considered in this work. It is worth noting that, the monitored data from these sensors will be sent to the cloud using the ThingSpeak application for monitoring purposes. Also, note that the sensors will be placed inside the garbage container for monitoring purposes while the Arduino WeMos microcontroller connected to these sensors will be mounted on top of the garbage lid. Figure 1 shows an overview of the developed communal garbage monitoring system. The system consists of the IoT nodes (i.e. Arduino with the sensors), cloud for storage and user interface.

The working function of the developed communal garbage monitoring system is illustrated in Figure 2. The communal garbage monitoring system will first read the data from all sensors every 1-minute interval. These real-time data will be stored in the cloud through the ThingSpeak applications. If the system indicates the level of the garbage inside the garbage container reaches 90% and above, a notification will be sent to the in-charge person through email and mobile application. The system will continue reading all the sensors for real-time monitoring.

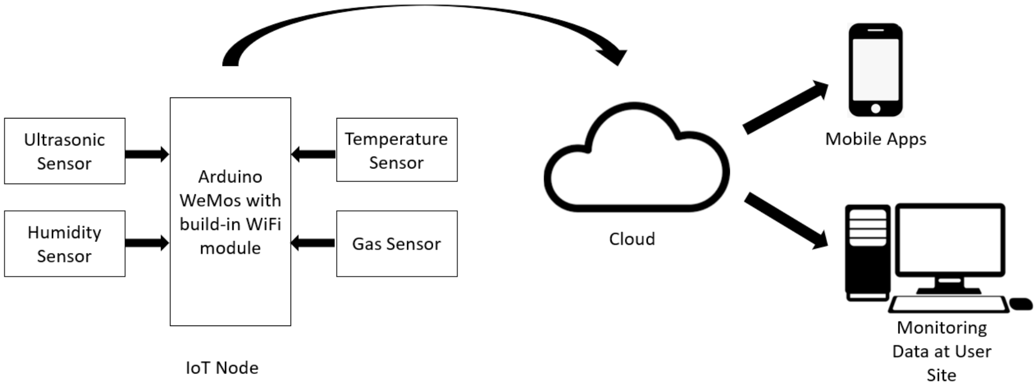


Figure 1. Communal garbage monitoring system overview

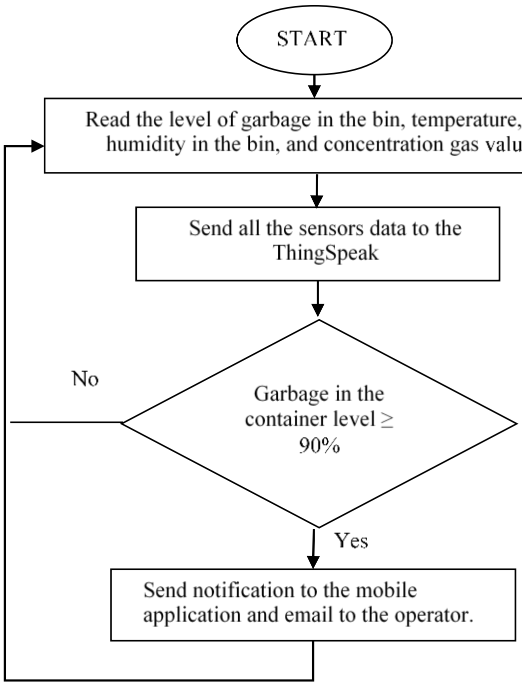


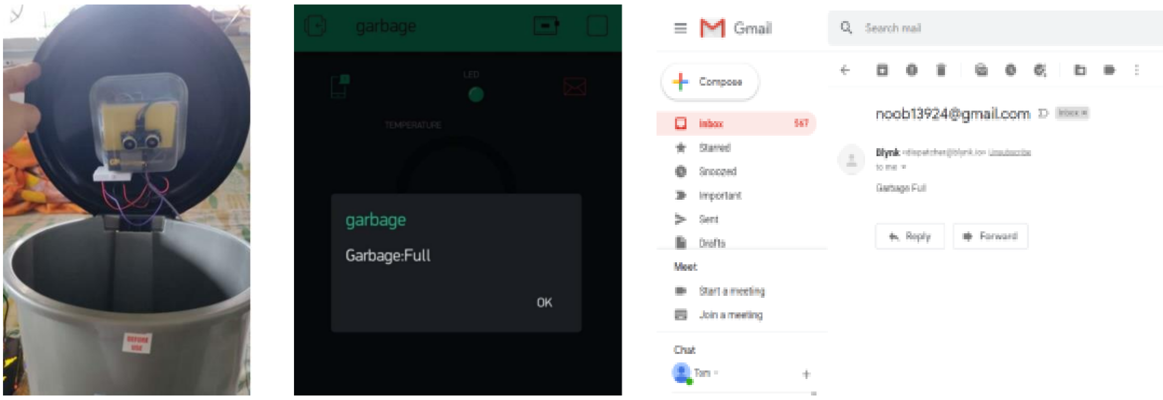
Figure 2. Flow chart of the developed communal garbage monitoring system

3. RESULTS AND DISCUSSION

In this section, the prototype development of the communal garbage monitoring system will be discussed. Then, data logging system for measured temperature, humidity and the gas concentration will be discussed. Also, the evaluation of results regarding the data logging system and the accuracy of the system obtained through the test-bed implementation of the developed communal garbage monitoring system will be explained.

3.1. Prototype of the developed communal garbage monitoring

The prototype of the developed communal garbage monitoring is as shown in Figure 3. As shown in Figure 3(a), the location of the sensors including the temperature, humidity, gas, and ultrasonic are located under the garbage container lid. In this work, the level of the garbage in the garbage container is measured considering two distances using ultrasonic sensors. The first distance is between the ultrasonic sensor located at the lid inside the container to the bottom of the garbage container (i.e. without and waste or garbage). The second distance is between the ultrasonic sensor and the waste or garbage inside the garbage container. Based on the two measured distances, the system will determine the differences between the two distances and convert the value into the percentage of the amount of garbage in the dustbin. As mentioned before, the developed system is designed to send the notification to the in-charge person when the level of garbage is more than 90%. Figure 3(b) shows the example of notification received in the mobile phone via Blynk Application software with a warning message of “Garbage Full”. Meanwhile, Figure 3(c) shows the example of the email notification sent by the system for notification purposes.



(a) (b) (c)

Figure 3. The developed communal garbage monitoring (a) communal garbage sensors location, (b) mobile apps notification, and (c) email notification

3.2. Data logging of the temperature, humidity, and the gas concentration

The developed communal garbage monitoring system is also integrated with the cloud for data storage and monitoring purposes. In this work, the system will send the temperature, humidity, and the level of gas concentration reading to the cloud via mobile apps. A test-bed implementation has been conducted considering an indoor location. The system will send the monitored data every one-minute interval. Figure 4 shows the collected data reading from the temperature sensors for a one-hour duration. The results show that the temperature reading is between 29.6 °C to 30.3 °C which is within the room temperature.

Meanwhile, Figure 5 shows the humidity reading measured using DHT 22 humidity sensor for a one-hour duration. The result shows that the humidity level inside the garbage container is between 73.25% and 74.75%. As indicated in Figure 5, the level of humidity is low in the first 45 minutes. This is because of the low temperature reading inside the garbage container as shown in Figure 4. However, the level of humidity starts to increase when the time is at 9.48 am. This is because of the decreasing temperature level in the garbage container as shown in Figure 4. Note that, the humidity level is inversely proportional to the temperature.

Meanwhile, the real-time value of the monitored gas concentration inside the garbage container for a 20 minutes duration is as shown in Figure 6. The results show that the level of the gas concentration is between is 0 PPM to 0.01 PPM. The low level of the gas concentration obtained through this experiment is low because of the low amount of garbage. Table 2 shows the air quality index used to indicate the status of the air quality.

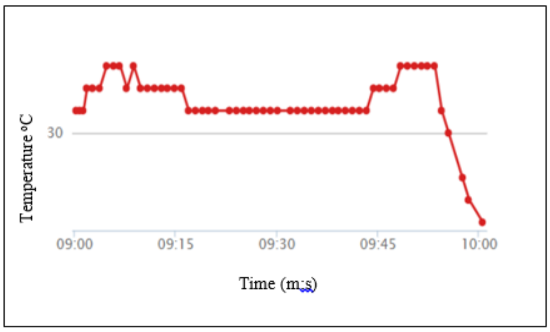


Figure 4. The temperature value insider the garbage container

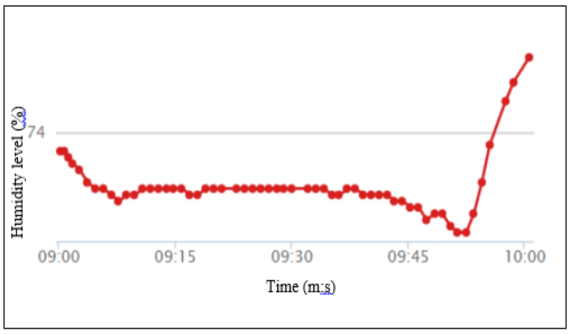


Figure 5. The humidity level inside garbage container

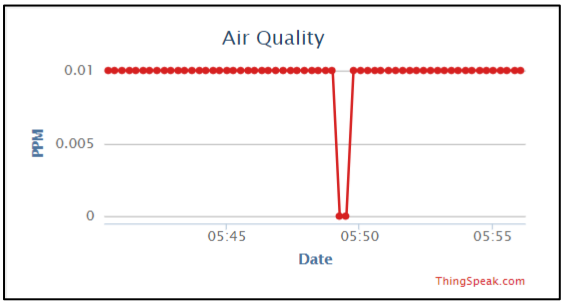


Figure 6. The gas concentration level inside the garbage container

Table 2. Air quality index [25]

Range (PPM)	Status
0-50	Good
51-100	Moderate
100-150	Unhealthy for sensitive group
151-200	Unhealthy
201-300	Very unhealthy
301-500	Hazardous

Based on the results obtained in Figures 4-6, we can conclude that the developed garbage monitoring system has high reliability. This is because the real-time monitored data has been successfully sent to the cloud (i.e. ThingSpeak) for storage and monitoring purposes during the duration of the test-bed implementation.

3.3. Accuracy of the developed garbage monitoring system considering different types of waste

In order to evaluate the accuracy of the developed garbage monitoring system, we considered four types of waste which are food waste, paper, plastic bottles, and metal. As mentioned before, an ultrasonic sensor is used to determine the height of the garbage to indicate the percentage of garbage inside the container, so that a notification will be sent out to the in-charge person when it exceeds 90%. To determine the accuracy of the developed system, the measured distance obtained from the ultrasonic sensor will be compared with manual measuring. For instance, the garbage is placed in the dustbin with a determined height of 16 cm from the ultrasonic sensor and the reading value from the ultrasonic sensor will then be compared with the determined height to calculate the accuracy. Note that, during the test-bed implementation, the measured distance using the ultrasonic sensor is repeated for three-time for each type of waste.

Table 3 shows the measured height of garbage by Ultrasonic sensor for three times compared to the preset garbage height is set manually inside the garbage container. The results shows that the food waste of garbage show highest error compared to the others type of garbage. Table 4 shows the percentage of the accuracy of the ultrasonic sensor in measuring the height of the garbage inside the garbage container. The accuracy of the sensor is calculated by (1) where the accuracy is difference of error from 100%.

Table 3. Garbage height measured by ultrasonic sensor compared to the manual measure

Garbage type	Preset height (cm)	Measured height (cm)				Error (cm)
		1st	2nd	3rd	Average	
Food waste	16	15.8	15	15.6	15.5	0.5
Plastic bottle	16	16	15.5	15.7	15.7	0.3
Paper	16	15.6	15.9	16	15.8	0.2
Metal	16	15.8	16	`15.7	15.8	0.2

$$Accuracy\ (\%) = 100 - \frac{Measured\ Error}{Preset\ Height} \times 100 \quad (1)$$

The result shows when the type of considered waste is a plastic bottle, paper, and metal, the percentage of accuracy is more than 98%. Meanwhile, for food waste, the accuracy of the developed system is 96.88% which indicates the lowest accuracy. This is because of the un-uniform shape of the food waste which reduces the ability of the sensors to give an accurate reading.

Table 4. Accuracy of ultrasonic sensor

Type of waste	Accuracy (%)
Food waste	96.88
Plastic bottle	98.13
Paper	98.75
Metal	98.75

4. CONCLUSION

In this work, a real-time communal garbage monitoring system has been developed with the aids of Internet of Things technology. The system is integrated with the cloud to monitor the temperature, humidity, and gas concentration inside the garbage container. Also, the system is equipped with a notification system to notify the in-charge person when the garbage container is nearly full. A test-bed implementation has been carried out and the results show that the system has high reliability. Besides, the results also indicated that using the ultrasonic sensor in the system can give an accuracy of up to 98.75% depending on the type of waste. This system can be used along with the development of the smart city to retain a healthy environment for the community.

5. LIMITATION AND FUTURE WORK

This work is a preliminary study on the development of real-time communal garbage monitoring system with the advantage of the internet of things. The air quality, humidity and temperature is measured and send to the cloud for monitoring. The real hardware validation still needs to be done in public communal garbage to validate the performance of the developed system. Besides, the location of the public communal garbage will be recorded for future development. This location is important to identify the specific communal garbage that need to be taking action by the operator.

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