An IoT Garbage Monitoring System for Effective Garbage Management

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***Abstract*—Nowadays, with the increasing output of municipal waste, the pressure on municipal waste treatment is increasing. In this case, utilizing low-cost and low-power IoT technology to improve urban waste management has become a popular trend. This paper proposes an intelligent garbage management system for urban communities: Garbage Manager. The Garbage Manager aspires to create energy-efficient and real-time waste detection based on IoT and data visualization technology. In this work, the NodeMCU chip integrated with a high-precision ultrasonic sensor is used to measure the height of the waste in the garbage bin and transmits the data to the database through the Ali-cloud IoT platform. In addition, a web page is created as a graphical user interface to display the status of the garbage bins in real-time. Experimental results show that the Garbage Manager is able to decrease the manpower from clearing the garbage by 24.07 % and reduce the garbage overflow times by 83.33 %.**

***Index Terms*—IoT, Garbage Management, Data Visualization**

I. INTRODUCTION

As the world's population continues to grow, the problem of waste disposal is becoming serious. According to recent surveys, the world generates more than 2.01 billion tons of municipal solid waste annually [1, 2]. Besides, China also generates thousands of waste yearly as shown in Figure 1 [3, 4]. The world will be surrounded by waste if the garbage disposal capacity is not improved. Recent literature works suggested that one of the most noteworthy methods to overcome waste disposal problems is to perform real-time garbage monitoring [5, 6]. On the other hand, considering that some toxic or flammable waste in the garbage bin might jeopardize the safety of the citizens, therefore, safety issues regarding garbage disposal are indispensable [7-9].

Governments have set up many traditional bins in public places scattered throughout the city. However, it is difficult for garbage collectors to track the exact situation of each garbage. Therefore, more workforce is required to reach the corresponding locations and perform garbage disposal tasks. This garbage collection method not only takes up an amount of manpower but also leads to inefficiency and rehandling. As a result, an intelligent garbage monitoring system that can display the bins' status in real-time is required. With the aid of the intelligent system, garbage collectors can dispose of the garbage bins when they are already full [10].

In this paper, an intelligent garbage management system, called Garbage Manager, has been established using IoT and data visualization technologies. The proposed system consists of four components, which are the garbage bin, hardware, cloud server, and web platform. Experiments have been conducted to verify the performance and effectiveness of the proposed Garbage Manager system.

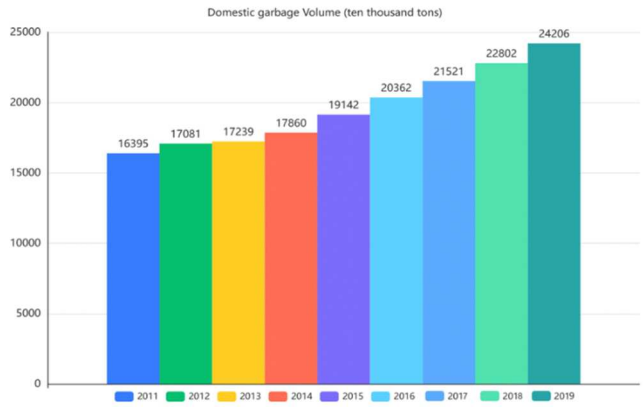

Fig. 1 Annual waste production in China (2014-2019) [3, 4]

II. LITERATURE REVIEW

To date, several researchers have focused on the garbage monitoring system with IoT. Likotiko, *et al.* [11] analyzed household waste disposal using smart bins equipped with advanced sensors. Combining levels of garbage information through the smart IoT system, the study found that household garbage disposal behaviour depends on the amount and content of the garbage bins. Besides, Hoque, *et al.* [12] utilised the advanced machine learning model and IoT to monitor and classify the garbage into biodegradable and non-biodegradable.

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In order to further improve the efficiency of garbage management, Vamsi, *et al.* [13] implemented an android mobile application which can notify the accumulated level of the garbage bins to related personnel. In their work, the shortest path to the garbage bin is provided through the android application.

Considering the requirement for energy supply, Raaju, *et al.* [14] utilised solar energy as a supplementary power supply to the garbage monitoring system. In their work, the system utilized Zigbee to implement several functions, such as data transmitting and edge computing to improve the response performance of the IoT system. In addition, safety issues are also paramount to focus on. For this reason, Savla, *et al.* [15] designed a real-time garbage monitoring system that provides a supervision strategy to avoid potential safety incidents.

Based on these previous studies, most of the solutions suggested are focused on garbage monitoring. In this paper, a dynamic web page that is able to intuitively display the state of each trash bin for real-time garbage monitoring system using IoT technology is proposed to improve the efficiency of waste disposal and reduce the labour burden.

III. DESIGN METHODOLOGY

In this work, the garbage monitoring system consists of four components which are garbage bins, hardware, cloud server, and web platform as shown in Figure 2. Figure 3 shows the flow chart of the garbage manager. The Garbage Manager implements internet interconnection and data transmission through WIFI-Module. Also, Garbage Manager constructs an advanced database to store relevant data. Ultimately, this work realizes an IoT-based garbage monitoring system that can efficiently help workers manage municipal waste.

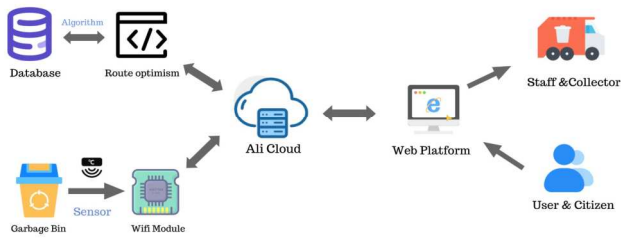

Fig. 2 Block diagram of the garbage manager

NodeMCU is used as an IoT platform. It initially included firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems and hardware based on the ESP-12 module. Besides, the ultrasonic module, HC-SR04 was selected in this work to measure the height of garbage. The ultrasonic sensor can calculate the current garbage level and send an alert signal to the server when the garbage level reaches the threshold limit. Also, Ali-cloud is used to store the collected data from the ultrasonic sensor as a server. Besides, this system also utilizes a graphical user interface for project deployment.

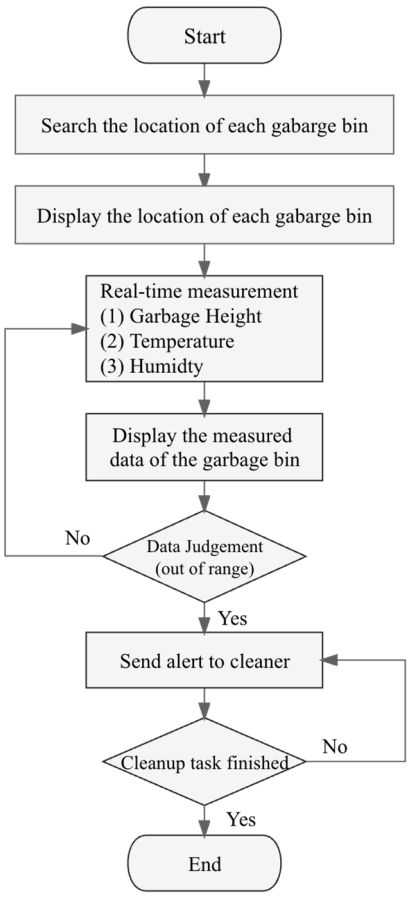

Fig. 3 Flowchart of the garbage manager

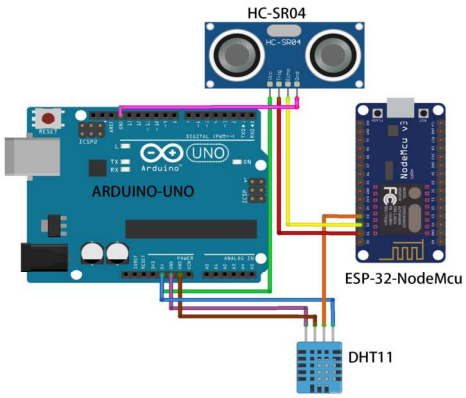

Fig. 4 Hardware connection for the garbage manager

In this work, temperature and humidity sensors are also used to monitor the garbage bin's temperature and humidity for safety purposes. DHT11 multifunctional sensor is used to measure both the temperature and humidity in the trash bin. When the temperature and humidity reach the threshold value, it will send the possible fire risk signal to avoid potential waste fire incidents. Figure 4 shows the hardware connection for the garbage monitoring system.

A java-web platform as a graphical user interface is developed in Ali-cloud's back-end to display the garbage bins' status. After data has been classified, the system will store the

data in the database for further viewing and processing. The garbage level and garbage bin status obtained from data processing will be reflected on the front-end website. Figure 5 shows the graphical user interface of the dynamic web page, where the administrator can observe the status of the garbage bins, including the overall garbage collection system and garbage levels for a specific trash bin. Data is presented dynamically to the administrator to ensure that it is available promptly.

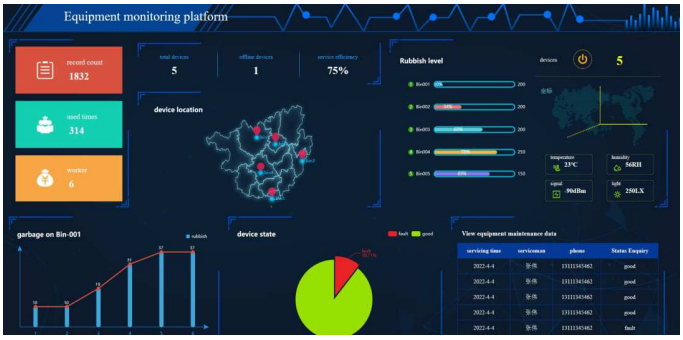

Fig. 5 Data visualization page of the system

IV. EXPERIMENT SETTING AND DATA ANALYSIS

To verify the effectiveness of the garbage monitoring device, an experiment is conducted on the trash bins in the student dormitory at Fuzhou University. There are six dormitory buildings in the living area, each dormitory building has about 860 people. The dimension of trash bins in the dormitory building is about $1.5\ m \times 0.5\ m \times 0.8\ m$, and there are specific garbage cleaners for each building. By default, the garbage bins need to be cleared three times a day by the garbage cleaner no matter how much garbage is in the trash bin. The clearing time is fixed at 8:00, 14:00, and 19:00. The trash bins are randomly selected in three dormitory buildings (#2, #3, #5) for investigation. The garbage device is installed in a transparent box as shown in Figure 6 so that the status of the devices can be easily viewed. The garbage device is placed underneath the ceiling of the trash bin as shown in Figure 7 to measure the height of the trash in the garbage bin. Since the system can automatically calculate the initial height of the trash bin, it is also suitable for trash bins with other dimensions. When the trash in the garbage bin exceeds 80% of the height of the trash bin, the website will alert the garbage cleaners by sending a notification. The cleaning and overflow times of each garbage bin before and after the installation of the garbage monitoring system are recorded.

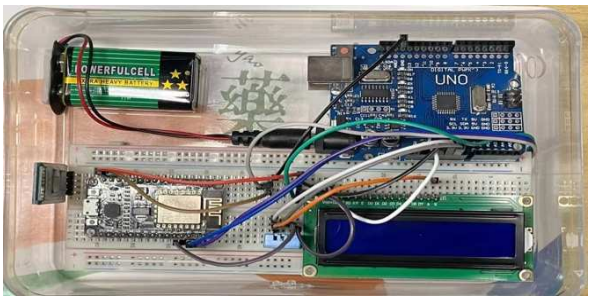

Fig. 6 The hardware of the Garbage Manager

Fig. 7 The Trash Bin equipped with Garbage Manager

After six days of monitoring, the cleaning times of three garbage bins before and after the implementation of the garbage monitoring system are obtained as tabulated in Table I whereas the overflow times of garbage bins before and after the implementation of the garbage monitoring system are recorded in Table II. Before being equipped with the monitoring device, the average number of garbage disposal tasks was 3 times a day. After being fitted with the device, the number was reduced to an average of 2.28 times a day, which was decreased by 24.07% as shown in Figure 8. Furthermore, the average daily overflow times of garbage bins decreased from 0.67 times to 0.11 times, which was reduced by 83.33%, as shown in Figure 9. Based on the experimental results, the Garbage Manager can effectively reduce the burden on the waste disposal tasks and improve the environment around the garbage bin.

TABLE I
NUMBER OF GARBAGE CLEARING SERVICES BEFORE AND AFTER THE IMPLEMENTATION OF THE GARBAGE MONITORING SYSTEM

	Bin #2		**Bin #3**		**Bin #5**	
	Before	**After**	**Before**	**Before**	**Before**	**After**
day1	3	2	3	2	3	2
day2	3	2	3	2	3	3
day3	3	3	3	3	3	2
day4	3	2	3	2	3	2
day5	3	3	3	2	3	3
day6	3	2	3	2	3	2
Total	18	14	18	13	18	14
Average	3	2.33	3	2.17	3	2.33

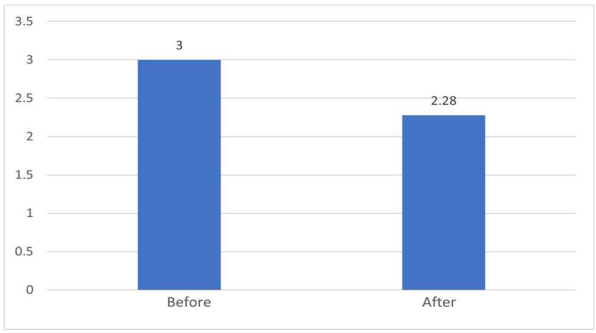

Fig. 8 Average number of cleanings

TABLE II
NUMBER OF GARBAGE BIN OVERFLOW TIMES BEFORE AND AFTER IMPLEMENTATION OF THE GARBAGE MONITORING SYSTEM

	Bin #2		Bin #3		Bin #5	
	Before	**After**	**Before**	**Before**	**Before**	**After**
day1	1	0	0	0	1	1
day2	0	0	1	0	1	0
day3	1	1	1	0	1	0
day4	1	0	0	0	0	0
day5	1	0	0	0	2	0
day6	0	0	1	0	0	0
Total	4	1	3	0	5	1
Average	0.67	0.17	0.5	0	0.83	0.17

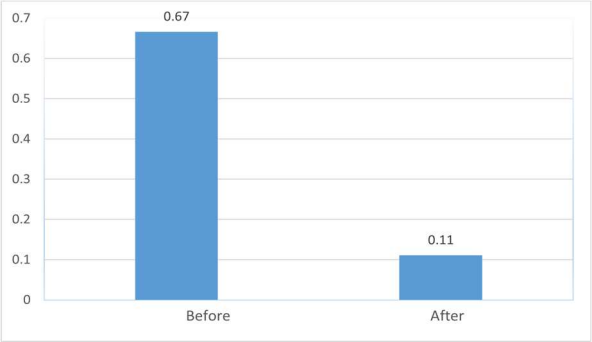

Fig. 9 Average number of overflows

V. CONCLUSION AND FUTURE WORK

In this paper, a garbage monitoring system is successfully implemented by utilizing various hardware, an advanced cloud server, and a graphical user interface. The proposed system can monitor the height level, temperature, and humidity of the garbage bin in real-time. The status of each garbage bin can be observed easily via the data visualization module which is the dynamic web page. Experimental results show that the proposed IoT garbage monitoring system can reduce garbage collection works by 24.07 % and reduce garbage overflow times by 83.33 %. The environment around the garbage bins has improved after being equipped with Garbage Manager.

In the future direction, the proposed system will be further improved by embedding a navigation algorithm to provide the shortest path to the garbage collection point. Furthermore, since the mobile platform has gradually become a popular trend, an Android App for monitoring systems will be included.

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