Jurnal Elektronika dan Telekomunikasi (JET), Vol. 24, No. 1, August 2024, pp. 12-16
Accredited by KEMDIKBUDRISTEK, Decree No: **158/E/KPT/2021**
doi: 10.55981/jet.560

Enhancing Urban Waste Management: An IoT-based Automated Trash Monitoring System

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Abstract

Industrial development nowadays affects the increase in types of packaging waste, which causes the accumulation of waste that has the potential to damage the environment. This research uses an Internet of Things (IoT) platform for an automatic waste volume monitoring system so that waste management in an area can be improved. The purpose of this research is to make it easier for the trashman to monitor the volume of the garbage collector through the notification feature. The research method used is the rapid application development methodology, starting with the requirement planning stage to analyze and identify the purpose of the system. Then, tools and system designs were created, followed by the development of the tools and system. Testing is used to evaluate the results of the tools and system. The result of the research is a prototype of an IoT-based automatic waste volume monitoring system featuring a volume detector for trash bins that indicates empty, almost full, and full conditions. The aim is to provide information to waste management officers more efficiently. The system also incorporates sensors for automatic opening and closing for user safety. Experimental testing demonstrates an average accuracy of 97%, with a 3% error margin, endorsing the system's effectiveness. However, it also highlights the need for further refinement to meet stringent waste measurement standards. These quantitative outcomes advocate for IoT-driven waste management solutions, emphasizing the continuous necessity for accuracy improvements.

Keywords: Internet of Things, monitoring system, waste, waste volume.

I. INTRODUCTION

One of the current community problems that are still being sought carefully for a solution is waste management in each region. Waste management has always been an important topic to be studied, and in some countries, the problem of waste management is one of the global problems that require special attention [1], [2]. In 2022, the National Waste Management Information System (SIPSN) data from the Ministry of Environment and Forestry (KLHK) in Indonesia, gathered from 202 regencies and cities, reported a national waste accumulation of 21.1 million tons [3]. Waste management that uses paradigms such as collecting, transporting, and disposing of waste has been proven to cause a lot of environmental problems. These problems include flooding due to clogged rivers, the release of dangerous concentrated liquids from garbage piles into local drinking water sources, and the occurrence of landslides of landfills. With the 3R principles (Reduce, Reuse, and Recycle), developed countries have recognized their success in managing their waste. It also needs adequate technological support [4]. With the development of the Internet of Things (IoT), the Internet can also be used for the purpose of overcoming the waste problem [5]. The IoT is used for developing a medium for intelligent device access in various sectors, including industry, households, and diverse sectors such as home and building automation, agriculture, environment, transportation, medical, and others [6]. IoT can be developed with the media of general electronic devices such as Arduino for specific purposes [7].

There are several previous studies related to designing IoT-based trash bins using the Telegram application. The result of this study is to monitor the trash by using a telegram [8]. The waste capacity monitoring has been investigated [4], where the result of this research is monitoring waste to prevent flooding. The study about created the design of a household waste destroyer based on a microcontroller and the IoT was done [9], the result is to produce a tool for destroying household waste. Implementation of the control system for home electronic devices was published [10], the study about an electronic control device that functions to automate electronic controllers with a remote monitoring system. Research about home electronic device control systems that produce electronic control devices that function were studied by [11], [12] to automate electronic controllers with remote monitoring systems using Arduino IDE as an open-source electronic prototyping platform based on interdependent hardware and software, flexible and easy to use [13], [14].

There are other similar studies regarding the design of IoT-based garbage collectors using the Telegram application [5], which is not equipped with a monitoring system, both website-based and mobile. In addition, other

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Received: July 13, 2023 ; Revised: November 08, 2023
Accepted: November 22, 2023 ; Published : August 31, 2024

studies have produced a waste capacity monitoring system to prevent flooding [4] not equipped with a notification system to each user, both trashman and the community as the party who disposes of the garbage, so it is still vulnerable to various things that can harm both parties, such as the spread of bacteria.

From several studies, the system built in this study produces more diverse features. In addition to monitoring the volume of the garbage collector through a website-based application, there is a mobile-based application that allows the monitoring process to be carried out more flexibly. Apart from that, the touchless feature in the built system can protect users from potential exposure to various kinds of bacteria in the trash.

The purpose of researching the tool for monitoring IoT-based garbage collectors is to simplify the process of monitoring garbage collectors through the Internet using the ThingSpeak web platform. The system will then be re-implemented based on its usefulness, applied to garbage collectors that open automatically, and send notifications to the Blynk application to convey information, serving as an indicator for full trash. With the monitoring of IoT-based garbage collectors, it is hoped to reduce the danger of bacteria and viruses caused by waste. It also provides more efficient time for the trashman in choosing a waste collection location.

In the next section, the results of the research are presented in more detail. Section II explains the proposed method for conducting this research. Section III presents the results of research related to the built system and the conducted testing. Section IV discusses the system that has been built as well as the discussion of the novelty of the research results. Finally, Section V presents the conclusion and limitations for further research development.

II. METHODS

A. Proposed Architecture System

The data modeling carried out in this study uses the ERD (Entity Relationship Diagram) approach, as shown in Figure 1. The system architecture presented in Figure 1 is made for a better and more structured database system so that it can be represented that the entities are interconnected with one another.

1) System Analysis

In the system operation, when a user approaches the garbage, the garbage collector opens automatically, allowing the user to dispose of the waste.

As shown in Figure 2, in the system, the user approaches the waste, specifies the type of waste, and monitors the waste bin through Blynk. If the waste bin

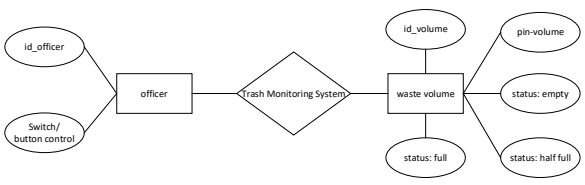

Figure 1. Entity relationship diagram.

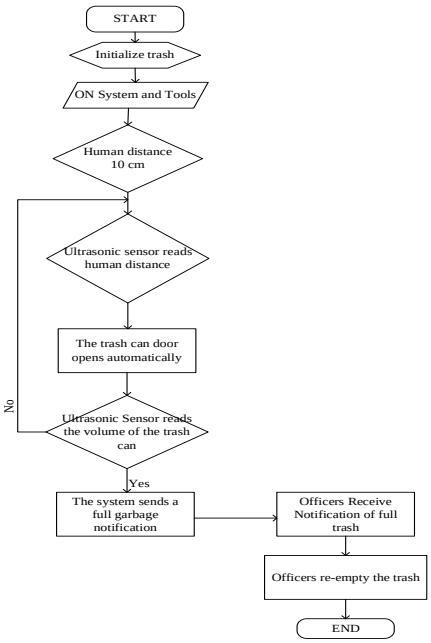

Figure 2. Waste monitoring system flowchart.

has reached the maximum capacity, a notification will be displayed, indicating that the waste bin is full and must be transported immediately.

2) Hardware Design

The hardware design will explain the device that will be used to implement an IoT-based automatic waste volume monitoring system, starting from Arduino, with ultrasonic sensors as the main component and other components as a supporter, which is described schematically in Figure 3.

The design of electronic circuits can be seen in Figure 3, which represents a series of several electronic components in schematic form in related systems that are used and integrated.

The implementation of the design in a garbage collector can be seen in Figure 4. In the design of the garbage collector system, there is an ultrasonic sensor that functions to detect the distance if someone approaches the garbage collector. The sensor will detect and open the lid of the garbage collector automatically with a distance limit between the user and the garbage collector of 10 cm. Regarding the monitoring of the garbage collector, it is done after the waste is put in the garbage collector. The ultrasonic sensor will detect the volume of waste and display information in the Blynk

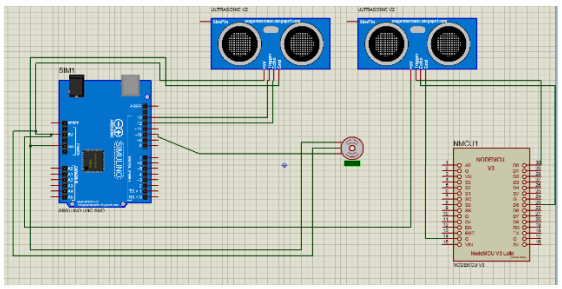

Figure 3. Electronic circuit design.

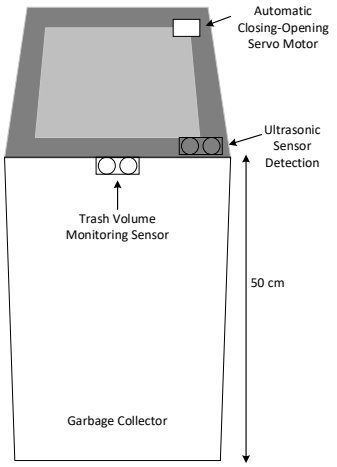

Figure 4. Automatic garbage collector design.

application and will send a notification through the application that has been built.

B. Modeling Process

At this stage, a data flow diagram is made based on the previous diagram design. The design in more detail from the data flow diagram is as follows:

1) Diagram Context

This diagram context describes the scope of a system. It shows all external entities that receive information or provide information to the system built, as shown in Figs 5 and 6.

2) Data Flow Diagram Level 1

The data flow diagram (DFD) represents a general analysis of the automatic garbage collector system. It was built to provide a structured understanding of the purpose and system workings, including the subsystems in it as a series of data that are interconnected with one another. In this system, DFD is presented regarding a system that can connect trashman and users (community) for automatic waste management through the system. A more detailed explanation regarding the system is presented in Table 1 and Table 2.

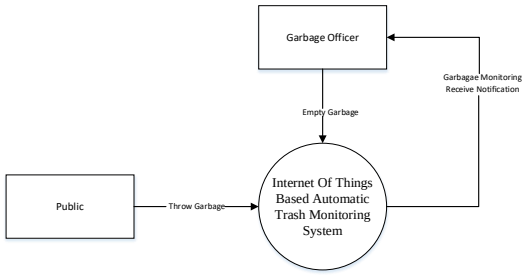

Figure 5. Garbage collector *diagram context monitoring*.

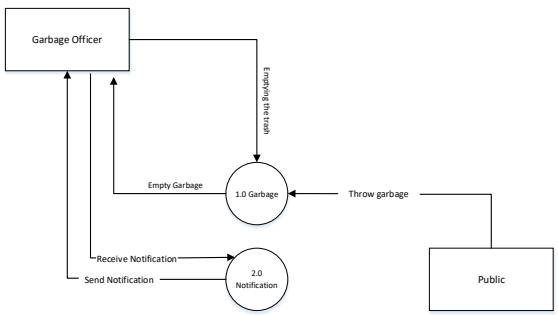

Figure 6. Data flow diagram level 1.

III. Research Result

A. Hardware Implementation

This stage is the manufacture of hardware for testing the volume monitoring system of the garbage collector that has been assembled and connected to the Arduino and Node MCU 8266 systems. The automatic garbage collector monitoring device can display the increased waste in real-time. It will send a notification to the trashman's telegram informing that the garbage is full and must be taken immediately. The hardware that has been built is shown in Figure 7.

B. Software Implementation

This stage displays the results of making a waste volume monitoring application that can monitor the volume increase remotely using the Blynk application, as shown in Figure 8.

Besides being able to be monitored using the Blynk application, the increased volume of garbage collectors can also be monitored using a web browser that has been provided by the IoT platform, which can be used for free to store and retrieve data using the HTTP protocol via the internet or local area network.

C. Result Discussions

1) Research Answer

In the conducted research, test results were obtained, including testing the distance between the user and the garbage collector. This involved testing the distance

TABLE 1
STORAGE IN DFD LEVEL 1

No.	Storage Name	Information
1	Trashman	A table in the database to store trashman data
2	Type of garbage collector volume	A table in the database to store the garbage collector volume type data

TABLE 2
PROCESSES INVOLVED IN DFD LEVEL 1

No.	Process	Incoming data flow (*Input*)	Outgoing data flow (*Output*)	Information
1	Trashman	*monitoring*	Receiving information	The trashman monitors the garbage collector then empties the garbage collector.
2	Type of garbage collector volume	Garbage collector volume	Volume Type	The trashman receives a notification that the volume level is full

Figure 7. Realization of the proposed system.

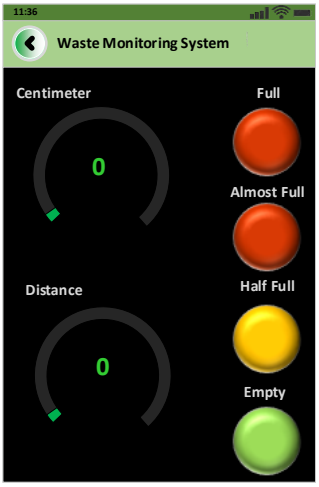

Figure 8. Blynk application view in the waste volume monitoring device.

measurement using an ultrasonic sensor HC-SR04 type outside the garbage collector. The purpose was to enable the lid open automatically using a servo motor as a hinge driver for the garbage collector lid. The results of the test data display are shown in Figure 9.

The delivery of an increased volume of garbage collector uses the Blynk and ThingSpeak applications so that users can control the waste volume. Therefore, users do not need to check manually and periodically.

Figure 10 shows the design results of the software display on the Blynk application which can be seen by users, both trashman and the community in monitoring

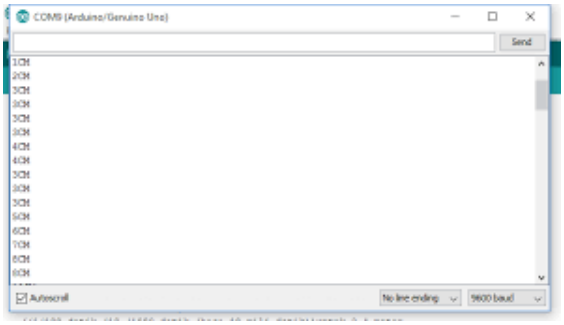

Figure 9. Ultrasonic sensor test results.

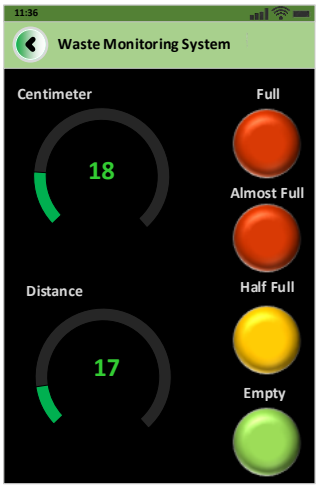

Figure 10. Waste volume display through blynk

the waste volume based on data obtained from the hardware.

2) Testing The System Built

This test aims to determine the level of effectiveness of the system that has been built as part of the research results. To find out the effectiveness of the related system, a manual comparison is carried out. Table 3 shows the result of a comparison of the system that has been built by comparing tools and manual measurements using a ruler and other measuring tools in accordance with measurement standards.

From the results of the table above, it can be seen that Error = 3%, with an average accuracy of 97%, this is based on the following accuracy formula:

$$Accuracy\ \% = \frac{Tool\ Value}{Manual\ Value}\ x\ 100$$

With an average error of 3% for all measurements and an accuracy of 97%, the research results are precise enough to be used as the reason for using an IoT-based garbage collector since the accuracy is quite effective [4]. With an error value of 3%, this instrument still needs further development to reduce the error value so as to provide information that is close to the truth value.

IV. DISCUSSIONS

From the results of tests that have been carried out on the related system, it can be seen that the average error

TABLE 3
TESTING RESULT

Experiment Number	Waste Height		Accuracy (%)
	Tool (cm)	Manual (cm)	
1	27	28	96
2	42	45	93
3	46	47	98
4	45	45	100
5	35	38	92
6	34	37	92
7	49	49	100
8	49	49	100
9	38	39	97
10	48	49	98
Mean			97

reaches 3%, and the accuracy rate is 97%, so the research results of the system that has been built can be said to be precise. This automatic trash system was built to provide a prototype for the development of the current waste management system in Indonesia so that it can provide system progress towards a better direction by utilizing IoT technology.

From the system design, it can be seen that in addition to the hardware of the automated system that is built to detect users who want to throw away the waste. This system is also equipped with an information system for users, both trashman and the community, regarding the volume of garbage collectors so that it can provide a more effective time for the trashman to pick up trash at each location in accordance with the notification received. This is made to avoid garbage collector that exceeds capacity so as to make garbage scattered and result in an unclean environment which then results in the emergence of various kinds of dangerous diseases. To avoid this, the system is also equipped with an ultrasonic sensor that can detect the user's distance. If the user is at a minimum distance of 10 cm, the garbage collector will open automatically so that the user's physical cleanliness can be maintained.

From several reference studies, it can be seen that the system built in this study has better features. In addition to monitoring that can be done through the website and mobile application, this system is also equipped with a touchless feature using a proximity sensor. This ensures that the garbage collector opens and closes automatically, preventing the risk of potential users (community) being exposed to various harmful bacteria.

V. CONCLUSION

The system built using Internet of Things (IoT) technology offers a practical solution to common waste management problems, such as scattered waste and overflowing garbage collectors. It automates the opening and closing of the garbage collector, promoting cleanliness and reducing the risk of bacterial contamination. Additionally, the system enables remote monitoring through internet connectivity, making waste collection more efficient for sanitation workers by saving time on manual checks. This innovation has the potential to transform waste management practices, preventing environmental issues such as flooding and pollution. It also serves as a valuable resource for policy development and the adoption of IoT-based garbage collectors in Indonesia, leading towards a more efficient and sustainable waste management system. Further development and the incorporation of intelligent algorithms are essential for enhancing this system and ensuring its long-term benefits for both waste collectors and the community.

DECLARATIONS

Conflict of Interest

The author declares no conflict of interest.

Credit Authorship Contribution

1st Author contributed to conceptualization, methodology, simulation, application development writing - original draft preparation, writing - review, proofreading, and editing. 2nd Author has contributed to conceptualization, supervision, and project administration. 3rd Author has contributed to conceptualization, methodology, software, and project administration.

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