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Home-based Waste Monitoring System using Internet of Things with Fuzzy Logic Method

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Abstract

The accumulation of waste in certain locations, especially in residential areas, due to the continuous accumulation of waste can cause environmental disturbances such as disease and unpleasant odors. This system is designed to find out whether the trash bin is full or not by applying fuzzy logic, if the status of the trash bin can be cleaned, it will be handled immediately so that the waste does not accumulate and disturb people around. This system can find out when the last time the waste was taken and the location of the trash bin as a prototype which can later be applied to areas with a wider range by cleaning service officers in Mamuju City. This system uses the HC-SR04 sensor to detect the distance of the waste to the sensor and uses the Load Cell sensor to detect the weight of the waste. Several tests were carried out, first by measuring the accuracy of each sensor used, the HC-SR04 sensor accuracy was obtained at 96.68% with an error of 3.32%. While the accuracy of the load cell sensor is 90.68% with an error of 9.32%. The second test calculates the sensor response time and Blynk notification response since the sensor detects waste, the average HC-SR04 sensor detection response is around 0.83 seconds. For the response time of incoming notifications when there is movement in the HC-SR04 sensor area has an average of 2.65 seconds. While the Load Cell sensor response time is only around 0.53 seconds. For Blynk notification response time since the Load Cell sensor detects it has an average of 2.51 seconds. The third test calculates the response time of the two sensors (HC-SR04 and Load Cell) and the Blynk notification response since the two sensors detected the waste, the average response time of the two sensors finished detecting only around 0.91 seconds. For the response time of the trash bin status condition, if there is movement in the area of the two sensors, the condition of the trash bin will change and display the status of Normal, Needs Cleaning and Highly Needs Cleaning with an average response time of 1.18 seconds. The system successfully sends notifications according to the fuzzy rules and expected to speed up the waste handling process.

Keywords—*Internet of Things, Trash Bin, Monitoring, Prototype, Fuzzy Logic*

1. Introduction

Waste is household waste that is no longer used and comes from various types of objects (Deda Widiantoro & Minsih, 2023). According to Alam et al. (2021), waste is also a nest of disease and various types of bacteria, so this object should not be ignored which triggers the emergence of piles of waste in existing trash bins.

Mamuju City, as the capital of West Sulawesi Province, is an area experiencing rapid population growth and development. This condition has an impact on the increase in the volume of waste produced every day, both from households, public facilities, traditional markets, and industrial activities. Based on observations, waste management in Mamuju City still faces various obstacles, ranging from the lack of modern waste management facilities to the lack of public awareness in disposing of waste in its place. One of the main problems is the limited number of adequate trash bins and the waste monitoring system which is still carried out manually. Many trash bins are often full before the collection schedule, so that piles of waste overflow onto the streets or surrounding areas. This creates an unhealthy environment, attracts flies and wild animals, and causes an unpleasant odor in the Mamuju area. This problem is exacerbated by the culture of some people who are still accustomed to littering because dirty waste conditions can be caused by piles of waste that make some people reluctant to dispose of t waste in its place, laziness is caused by the smell and dirt and having to keep opening and closing the trash bin (Gusniarti, 2020). On the other hand, the cleaners who are tasked with cleaning and transporting waste face challenges in managing the number of trash bins spread across various locations in the Mamuju city area due to manual checking of trash bins. Cleaning officers are required to check trash bins by visiting each trash bin located at several locations registered with the Mamuju City Environmental and Sanitation Office to maintain the cleanliness of the city's trash bins. The manual system that requires them to check each trash bin location one by one results in wasted time and energy, reduces work efficiency, and increases operational costs. This method is less effective because it will take longer and reduce the performance of waste officers in doing their jobs as well as higher costs. This phenomenon shows that waste management in Mamuju City has reached an emergency level and requires technology-based solutions, considering the rapid development of technology in this era, this problem should be able to be overcome.

With the Internet of Things (IoT), this problem can be overcome through the innovation of smart trash bins that can provide real-time information to cleaners about the condition of the trash bin. This will not only increase the efficiency of waste management, but also create a cleaner, healthier, and more comfortable city environment for the people of Mamuju City, from this situation the author took the initiative to create a tool that functions to monitor the contents of the trash bin using an Arduino microcontroller, ESP8266 and ultrasonic sensors (Imran et al., 2020). Researchers propose a smart trash bin system monitoring that can send real-time waste condition status data to the database and the data can be monitored on the Android application. The data received on the Android application is changed with an attractive User Interface so that if the waste load status and weight status are filled or full, there will be a color indicator showing the status of the waste condition. In addition, cleaning officers will also receive notifications regarding the actions and current status of the trash bin processed by Firebase Cloud Messaging (FCM) so that cleaning the waste can be done quickly and easily. The process of detecting the waste load uses an HC-SR04 ultrasonic sensor connected to a NodeMCU microcontroller. NodeMCU functions as a data transmission and processing medium. Based on the research "Designing a Smart Trash Bin Using an Arduino-Based Fuzzy Logic Algorithm" a trash bin has been created that uses 2 sensors that can detect humans and trash loads, but in this study it is not yet Android-based. Then based on the research "Designing a Smart Trash Bin Using an Arduino-Based Fuzzy Logic Algorithm" a trash bin was designed that can turn on LED lights and buzzers based on the height of the trash bin but is not yet Android-based (William et al., 2019). And based on the research "Trash Bin Information System with Web-Based Monitoring and WhatsApp Assisted by Arduino Mega 2560", trash bin monitoring is already Android-based. Trash bin load data will be sent via the internet and sent back to the Android application, but in this study the application used uses a third-party application, namely: WhatsApp (Suandi et al., 2018). Based on previous research, researchers provide solutions and innovations to the system that has been created, namely by creating a smart waste can that has been integrated with an Android application that can monitor the garbage load in real-time using Push Notification technology in notifications to garbage officers. This IoT-based smart trash bin is a tool that functions to monitor whether the garbage is full and provides real-time information to the connected application automatically. This system applies a Fuzzy Logic algorithm to determine the actions that garbage officers must take based on the level of waste load and the last time the trash bin was cleaned. The data obtained will be used to determine notifications on the Android application, which data will be processed using the Firebase Cloud Messaging (FCM) application. The process carried out on Firebase Cloud Messaging (FCM) is set using the Pusher or Blynk application with the Python programming language, so that notifications will still be received by application users to take garbage cleaning actions.

2. Method

1. Research Stages

Figure 1 illustrates the problem-solving process and the research implementation stage. The design of the trash bin monitoring system is carried out through several stages as presented in Figure. The stages in this research start from identifying the problem, collecting data, designing the system, building the system, testing the system, analyzing and do corrections, then make a report.

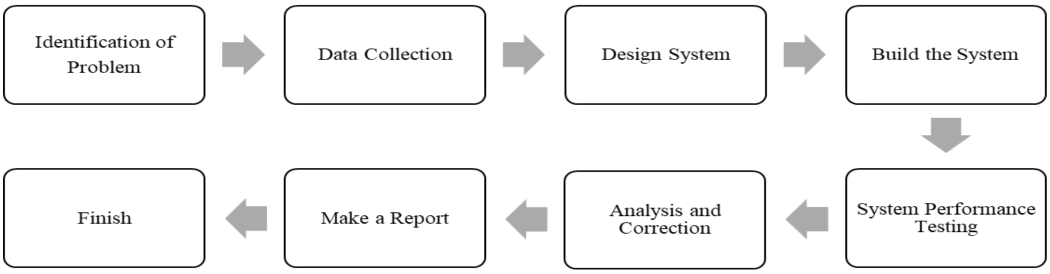

Figure 1. Research Stages

2. System Flowchart

Figure 2 is a flow diagram illustrating the working process of an Internet of Things-based home waste monitoring system.

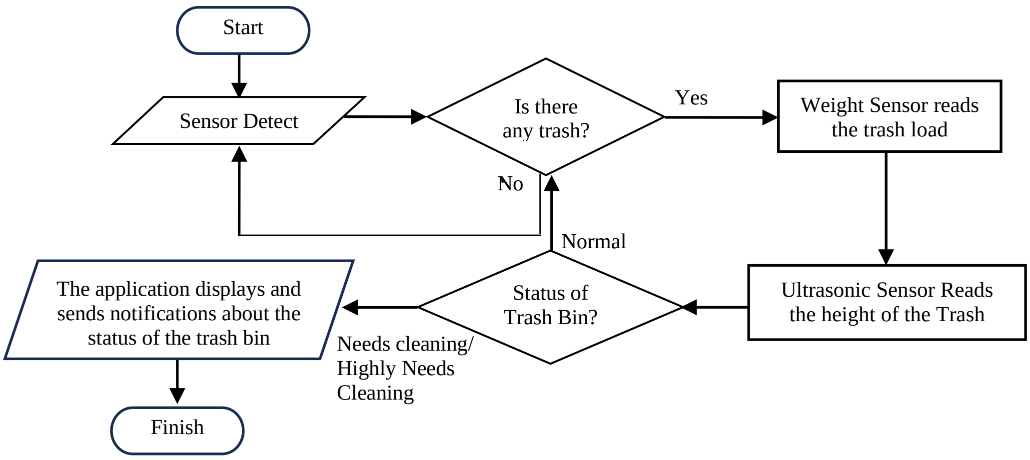

Figure 2. System Flowchart

The flowchart above explains how the system works. The process starts with the detection of waste using sensors. If waste is detected, the weight sensor reads the weight of the waste, while the ultrasonic sensor measures the height of the waste inside the bin. The data from both sensors is analyzed to determine the status of the bin, whether it is in normal condition or requires cleaning. If it requires cleaning, the app automatically displays the status of the bin and sends a notification to the cleaner. With this system, bin management becomes more efficient and monitored in real-time.

3. System Architecture

Figure 3 shows a block diagram of a system using the Internet of Things (IoT). IoT (Internet of Thing) can be defined as the ability of various devices to be connected to each other and exchange data through the internet network (Suhendar et al., 2021). IoT is a technology that allows for control, communication, cooperation with various hardware, data through the internet network. So it can be said that the Internet of Things (IoT) is when we connect something (things) that are not operated by humans, to the internet (Lestari et al., 2023).

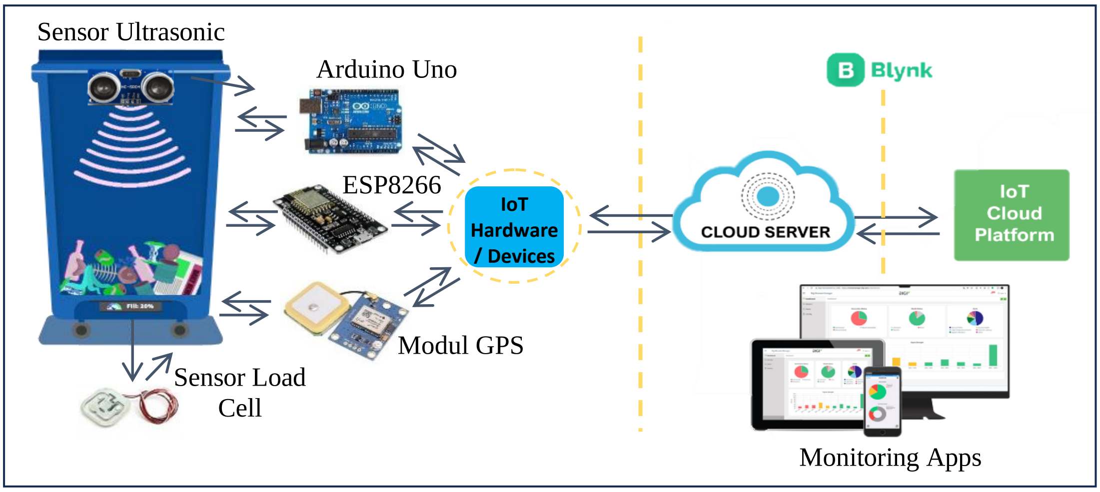

Figure 3. System Block Diagram

The perception layer is a layer consisting of sensors and devices used to receive data from the environment that is converted into digital form and then distributed to the network layer (Pratama et al., 2022). Examples of sensors that can be used include ultrasonic sensors and load cells, devices that can receive data from the environment. The second layer is the network layer, which functions to connect the sensor layer to the application layer. This layer determines the information, data processing is carried out at this layer, network capabilities and how data is sent are determined at this layer (Ghazian, 2019). The Arduino or ESP8266 microcontroller module is used to process sensor data and send it to the cloud server and the Ublox Neo-6m GPS Module to send the location of the trash bin to the cloud server for position tracking. The Application Layer is the last layer in the IoT architecture used as an easy-to-use interface for users connected to the network layer (Hutabarat & Mathias, 2023). Users can communicate with the sensor layer to obtain data that suits their needs such as the height and weight of the waste, whether the bin needs to be cleaned or not and the trash bin location, which can be accessed from the Mobile application or Website.

4. Circuit Design

IoT circuit design in addition to system architecture, also illustrates the circuit design using a fritzing diagram, Fritzing is an open source initiative to develop software for designing electronic hardware (Haidar, 2023). The system circuit in the form of an Arduino Uno R4 controller, NodeMCU ESP8266, HC-SR04 ultrasonic sensor, Load Cell sensor and Ublox Neo-6m GPS Module is used to build this IoT-based home waste system. Figure 4 shows the components of a waste monitoring system where all sensors are connected to the Arduino controller:

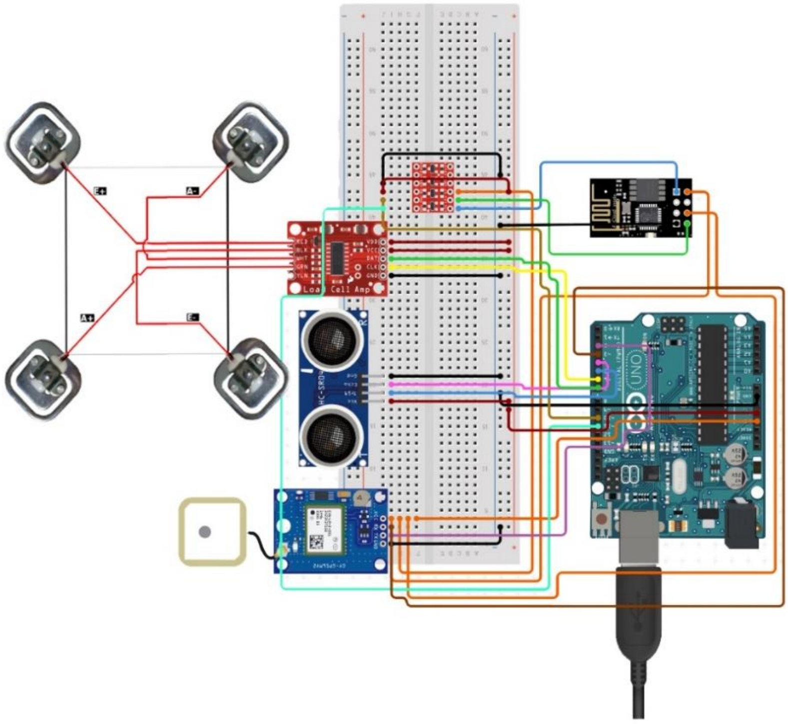

Figure 4. Circuit Design

2.4.1 Arduino Uno R4

Arduino Uno R4 acts as a sensor control center to coordinate input from various sensors and regulate data flow between components (Waroh et al., 2020). In this system, Arduino menjadi main control center which collects data from installed sensors, such as the HC-SR04 sensor and Load Cell sensor. Arduino processes initial data from sensors and sends it to NodeMCU for further processing.

2.4.2 *NodeMCU ESP8266*

NodeMCU ESP8266 was chosen because it has a WiFi module that supports IoT communication. NodeMCU ESP8266 is the connectivity center of the system that is tasked with receiving data from Arduino and sending it to the cloud, specifically Firebase Realtime Database (Wijaya et al., 2023). With integrated WiFi capabilities, the NodeMCU allows the system to send notifications directly to the user's Android app. NodeMCU was chosen because it can send waste condition data to the user's smartphone in the form of notifications when the capacity of the bin needs to be cleaned.

2.4.3 HC-SR04 Sensor

HC-SR04, otherwise known as an ultrasonic sensor, is used to measure the height of a pile of waste in a trash bin. This sensor sends out an ultrasonic signal, which is then reflected back by the object in front of it (Purwanto et al., 2019). If the height of the bin reaches a certain limit, the NodeMCU will send a signal to Firebase to let you know that the bin is full. HC-SR04 in the context of this research has an important role in monitoring the height of the pile of waste in the trash bin. By measuring the distance between the trash bin lid and the pile of waste, this sensor can detect whether the trash bin needs to be cleaned or not.

2.4.4 Load Cell Sensor

Load cell sensor is used to measure the load or weight of the waste in the bin (Putra & Arsanto, 2024). The use of the sensor ensures that the system not only detects the height of the waste but also its weight. Data from the Load Cell provides an indicator of the waste load, needed because it provides additional measurements besides the height of the waste. The data from the Load Cell sensor is combined with the height data from the HC-SR04 to provide an accurate picture of the waste capacity. With this, the system can reduce false alerts if only the height of the waste is full but the weight has not reached the capacity.

2.4.5 GPS Ublox Neo-6m Module

The Ublox Neo-6m GPS module helps in tracking the location of the waste bins. This is useful if the system is to be implemented on a wider scale, such as an urban waste management system. The location data from the GPS module is synchronized with the waste capacity data and then sent to Firebase, so that users or cleaners can find out the location of trash bins that need to be emptied immediately. With GPS location integrated with waste condition data, users can easily find the location of the nearest trash bin that needs to be emptied or picked up immediately.

2.4.6 Firebase Realtime Database and Notifications

Firebase Realtime Database stores real-time data from sensors connected to NodeMCU. This data includes the height and weight of the waste as well as the location of the trash bin. The system then utilizes Firebase Cloud Messaging (FCM) and the Python-based Pusher application to manage notification delivery. Once the data shows that the trash bin is full, FCM will send an instant notification to the user via the Android application (Juansen & Simatupang, 2023), ensuring users always have the most up-to-date information about the status of their trash bin.

2.4.7 Fuzzy Logic

The implementation of fuzzy logic is needed in this study, fuzzy logic itself is a logic that has true and false values and is used for decision making (Nurjanah et al., 2023). In this study, the trash monitoring system uses two main sensors, namely the HC-SR04 sensor and the load cell sensor. The HC-SR04 sensor functions to detect the height of the volume of waste in the trash bin, while the load cell sensor is used to detect the weight of the waste. The data generated from these two sensors is then used together with the last cleaning time data (timestamp) to determine the status of the trash bin using the fuzzy logic method. Based on data from the two sensors, there are three fuzzy variables used to determine the status of the trash bin, namely:

1. *Last Cleaning Time (LCT)*: Shows when the trash bin was last emptied, measured based on the timestamp from the NodeMCU.
2. *Waste Load (WL)*: Refers to the volume of waste in the trash bin, which is measured using the HC-SR04 sensor. The height value of the waste from the centimeter scale is converted to a scale of 0% - 100% based on the maximum height of the trash bin. The closer to 100%, the closer the distance of the waste to the sensor, vice versa.
3. *Waste Weight (WW)*: Indicates the weight of the waste in the trash bin, which is detected by the load cell sensor in kilograms with a maximum weight of 5 kg.

Several fuzzy rules used to determine the status of the trash bin and the actions taken by the Cleaning Officers in this study can be seen in table 1, below:

Table 1. Fuzzy Rules in Waste Monitoring System

Logic-	Last Cleaning Time (LCT)	Waste Load (WL)	Categories (WL)	Waste Weight (WW)	Categories (WW)	Trash Bin Status
1	0-8 jam	Low	0% - 50%	Low	0 kg – 2,4 kg	Normal
2	0-8 jam	Low	0% - 50%	High	2,5 kg – 5 kg	Needs cleaning
3	0-8 jam	High	51% - 100%	Low	0 kg – 2,4 kg	Needs cleaning
4	0-8 jam	High	51% - 100%	High	2,5 kg – 5 kg	Highly Needs cleaning
5	8-16 jam	Low	0% - 50%	Low	0 kg – 2,4 kg	Normal
6	8-16 jam	High	51% - 100%	Low	0 kg – 2,4 kg	Highly Needs cleaning
7	8-16 jam	Low	0% - 50%	High	2,5 kg – 5 kg	Highly Needs cleaning
8	8-16 jam	High	51% - 100%	High	2,5 kg – 5 kg	Highly Needs cleaning
9	>16 jam	Low	0% - 50%	Low	0 kg – 2,4 kg	Needs cleaning
10	>16 jam	Low	0% - 50%	High	2,5 kg – 5 kg	Highly Needs cleaning
11	>16 jam	High	51% - 100%	Low	0 kg – 2,4 kg	Highly Needs cleaning
12	>16 jam	High	51% - 100%	High	2,5 kg – 5 kg	Highly Needs cleaning

1. [R1] If *LCT* is 0-8 hours, *WL* is low (0% - 50%), and *WW* is low (0 kg - 2.4 kg), then the status of the bin is Normal.
2. [R2] If *LCT* is 0-8 hours, *WL* is low (0% - 50%), and *WW* is high (2.5 kg - 5 kg), then the status of the bin is Needs cleaning.
3. [R3] If *LCT* is 0-8 hours, *WL* is high (51% - 100%), and *WW* is low (0 kg - 2.4 kg), then the status of the bin is Needs cleaning.
4. [R4] If *LCT* is 0-8 hours, *WL* is high (51% - 100%), and *WW* is high (2.5 kg - 5 kg), then the status of the bin is Highly Needs cleaning.
5. [R5] If *LCT* is 8-16 hours, *WL* is low (0% - 50%), and *WW* is low (0 kg - 2.4 kg), then the status of the bin is Normal.
6. [R6] If *LCT* is 8-16 hours, *WL* is high (51% - 100%), and *WW* is low (0 kg - 2.4 kg), then the status of the bin is in High Needs cleaning.
7. [R7] If *LCT* is 8-16 hours, *WL* is low (0% - 50%), and *WW* is high (2.5 kg - 5 kg), then the status of the bin is Highly Needs cleaning.
8. [R8] If *LCT* is 8-16 hours, *WL* is high (51% - 100%), and *WW* is high (2.5 kg - 5 kg), then the status of the bin is Highly Needs cleaning.
9. [R9] If *LCT* is more than 16 hours, *WL* is low (0% - 50%), and *WW* is low (0 kg - 2.4 kg), then the status of the bin is Needs cleaning.
10. [R10] If *LCT* is more than 16 hours, *WL* is low (0% - 50%), and *WW* is high (2.5 kg - 5 kg), then the status of the bin is In Highly Needs Cleaning.
11. [R11] If *LCT* is more than 16 hours, *WL* is high (51% - 100%), and *WW* is low (0 kg - 2.4 kg), then the status of the bin is in Highly Needs cleaning.
12. [R12] If *LCT* is more than 16 hours, *WL* is high (51% - 100%), and *WW* is high (2.5 kg - 5 kg), then the status of the bin is in Highly Needs cleaning.

3. Results And Discussion

1. Result of System Design

This section presents the result of the design of a home waste monitoring system. Figure 5 shows a prototype design model and the Internet of Things circuit is implemented. A prototype of a home waste monitoring system with a capacity of 10 liters with a size of 30 cm x 10 cm with an ultrasonic sensor used to measure the height of the waste and a load cell sensor to measure the weight of the waste load.

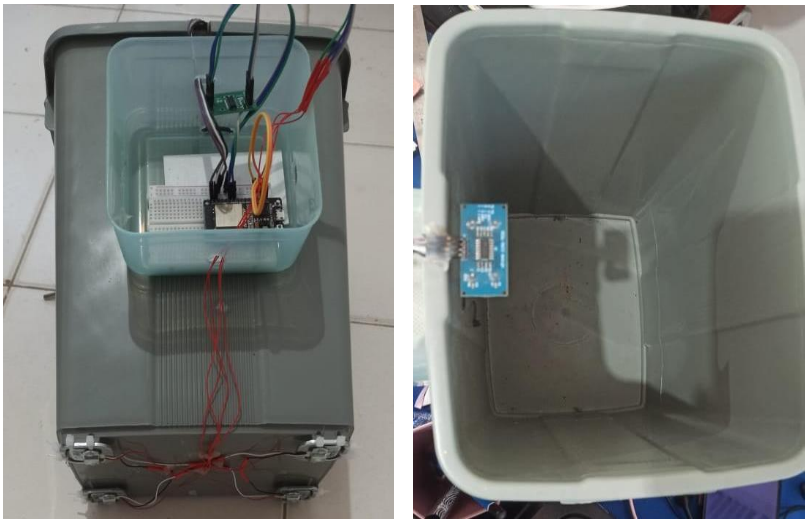

Figure 5. Result of System Design

2. Application and Codes

The software on the home waste monitoring system is programmed using the Arduino IDE software. Arduino IDE is software used as a medium for programming on the board to be programmed (Kamal et al., 2023). The programming language used in this programming is C++ which is a complicated C derivative language because you have to learn again how to write them which are different from Java and Delphi (Nasruddin & Kusmanto, 2023). The image below shows the program of the trash system.

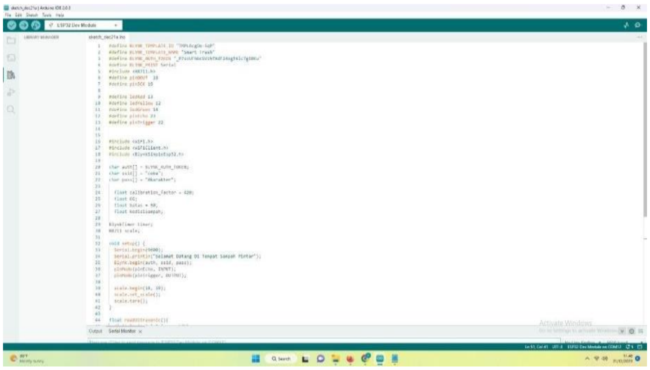

Figure 6. Waste Monitoring System Program

3. Testing Results

Testing has been carried out to determine the success of each module used in the waste bin monitoring system series, so a series of tests were carried out as follows.

3.3.1 Ultrasonic Sensor Testing

In this test, theoretical comparisons will be made with actual values. Table 2 shows the results of the HC-SR04 ultrasonic sensor test which was carried out in 8 tests. This test was conducted to measure the accuracy of the HCSR-04 ultrasonic sensor in measuring distance. This test is carried out by comparing the actual distance measured using a ruler with the distance reading on the sensor.

Table 2. Ultrasonic Sensor Testing

Testing-	Manual Scales (cm)	Ultrasonic Sensor Readings (cm)	Difference	*Error (%)*
1	8 cm	7,5 cm	0,5	6,25
2	**10 cm**	**9,3 cm**	**0,7**	**7,00**
3	12 cm	11,4 cm	0,6	5,00
4	15 cm	14,6 cm	0,4	2,67
5	18 cm	17,4 cm	0,6	3,33
6	19 cm	18,8 cm	0,2	1,05
7	22 cm	22 cm	0,0	0,00
8	24 cm	23,7 cm	0,3	1,25
Average of Error				3,32 %

From the test results, the average error obtained is 3.32%, it can be seen that the accuracy level of the ultrasonic sensor in this study is 96.68%. How to calculate the error obtained from the comparison of measurements between the ruler and the ultrasonic sensor can be calculated by the formula:

$$Error = \frac{|\,Measurement\ Value - Reference\ Value\,|}{Reference\ Value} \times 100\ \% \qquad (2)$$

$$= \frac{10 - 9{,}3}{10} \times 100\ \%$$

$$= 7{,}00\%$$

Figure 7. Ultrasonic Sensor Installation

3.3.2 Load Cell Sensor Testing

Similar to the previous test, this test will be compared in theory with the actual value. Table 3 shows the results of the Load Cell sensor test which was carried out in 8 tests. This test is carried out to measure the accuracy of the Load Cell sensor in reading the weight of the scale. This test is done by comparing the actual weight using the scales with the load cell sensor reading.

Table 3. Load Cell Sensor Testing

Testing-	Manual Scales (Kg)	Load Cell Sensor Readings	Difference	*Error (%)*
1	4 kg	3,8 kg	0,2	5,00
2	3,5 kg	3,4 kg	0,1	2,86
3	**3 kg**	**2,75 kg**	**0,25**	**8,33**
4	2,5 kg	2,5 kg	0,0	0,00
5	2 kg	1,9 kg	0,1	5,00
6	1,5 kg	1,3 kg	0,2	13,33
7	1 kg	0,85 kg	0,15	15,00
8	0,8 kg	0,6 kg	0,2	25,00
Average of Error				9,32%

From the test results, the average error obtained is 9.32%, it can be seen that the accuracy level of the Load Cell sensor reading in this study is 90.68%. How to calculate the error obtained from the comparison of measurements between the ruler and the ultrasonic sensor can be calculated by the formula:

$$Error = \frac{|\ Measurement\ Value - Reference\ Value\ |}{Reference\ Value} \times 100\ \% \qquad (3)$$

$$= \frac{3 - 2{,}75}{3} \times 100\ \%$$

$$= 8{,}33\%$$

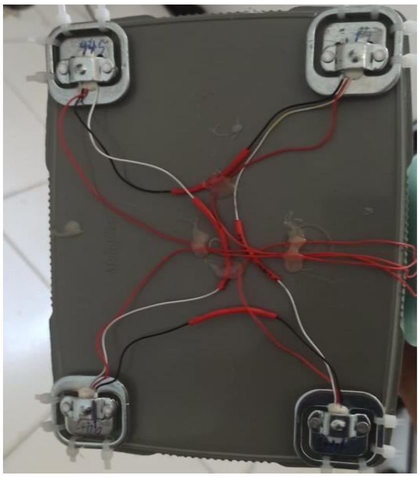

Figure 8. Load Cell Sensor Installation

3.3.3 Blynk Notification Testing

Blynk is a digital dashboard that offers graphical interface facilities and supports various hardware used in Internet of Things projects (Setiawan & Junianto, 2024). Notification on the Blynk application will appear when the indicator or status of the waste is “Needs cleaning” and “Urgently needs cleaning”, then the ESP8266 module will send a notification in the form of a message to the Blynk application that the trash needs to be cleaned. The average time range of notifications that enter the Blynk application after receiving the output of the ultrasonic sensor and load cell sensor is as follows:

Table 4. Time for Notification to be Sent since HC-SR04 Sensor Detected Waste

Testing	Trash Bin Status	Detection Time HC-SR04 Sensor	Blynk Indicator	Notification Response Time
1	Normal	0,72 s	Off	2,3 s
2	Needs Cleaning	0,89 s	On	2,8 s
3	Normal	0,75 s	Off	2,1 s
4	Needs Cleaning	0,91 s	On	3,4 s
5	Normal	0,79 s	Off	2,1 s
6	Needs Cleaning	0,93 s	On	3,2 s
	Average	0,83 s		2,65 s

Based on the Notification Response Time data since the HC-SR04 Sensor detects waste, a fast sensor response time is obtained where the average detection of the HC-SR04 sensor is less than 1 second or only around 0.83 seconds. For the response time of incoming notifications when there is movement in the HC-SR04 sensor area has an average of 2.65 seconds.

Table 5. Time for Notification to be Sent since Load Cell Sensor Detected Waste

Testing	Trash Bin Status	Detection Time Load Cell Sensor	Blynk Indicator	Notification Response Time
1	Normal	0,54 s	Off	2,1 s
2	Needs Cleaning	0,51 s	On	2,5 s
3	Normal	0,58 s	Off	2,3 s
4	Needs Cleaning	0,49 s	On	2,7 s
5	Normal	0,56 s	Off	2,4 s
6	Needs Cleaning	0,52 s	On	3,1 s
	Average	0,53 s		2,51 s

Based on the Notification Response Time data since the Load Cell sensor detects waste, it is obtained that the sensor response time is faster than the HC-SR04 sensor where the average detection of the Load Cell sensor is less than 1 second or only around 0.53 seconds. For the response time of incoming notifications when there is movement in the Load Cell sensor area has an average of 2.51 seconds.

3.3.4 Blynk Application Testing

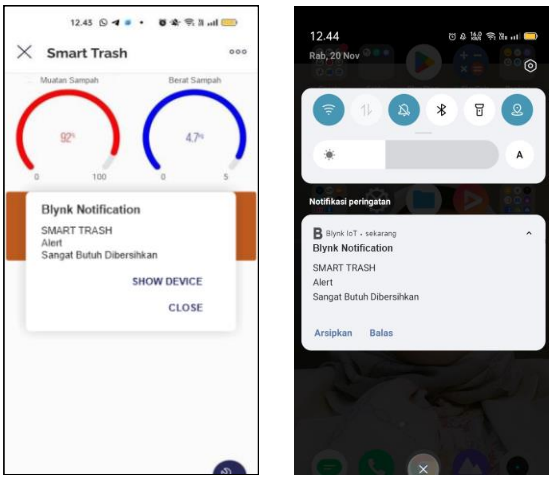

Figure 9. Blynk Notification

Figure 9 shows an example of a monitoring system display if both sensors work successfully and send notification of waste status based on fuzzy logic rules. The NodeMCU ESP8266 connection process with the Blynk application via a Wi-Fi connection, connected to the program and will be displayed via a serial monitor with the Baudrate used in Wi-Fi module communication is 9600 bps, if successfully connected to the Blynk and Wi-Fi application then the writing Connected to Wi-Fi and Blynk will appear.

3.3.5 Discussion of Test Results and Analysis

The trash bin monitoring system tool that has been made will be placed at the research location, this application will display indicators of waste load, waste weight and trash bin condition status through the Blynk application as seen in Figure 9. The trash bin has a size of 30 cm long, 10 cm wide, and weighs 300 grams per trash can. Testing the whole set of trash bin monitoring system is done by putting the trash bin, while the user monitors the trash bin. To activate this trash bin, it must be connected to an internet connection, so that the NodeMCU ESP8266 can send notifications of waste volume, and the location of the trash bin can be controlled through the Blynk application. The following are the results of the tests carried out as follows.

Table 6. Time Status Response "Trash Bin Condition"

No.	Last Cleaning Time (LCT)	HCSR-04 Sensor Detection	Load Cell Sensor Detection	Time Both Sensors Finish Detecting	Time Status Response	Status of Trash Bin Condition
1.	2 Hours	75%	3,7 kg	1,01 s	1,37 s	Highly Needs Cleaning
2.	4 Hours	60%	3,0 kg	0,94 s	1,24 s	Highly Needs Cleaning
3.	8 Hours	55%	2,7 kg	0,87 s	1,15 s	Needs Cleaning
4.	16 Hours	45%	1,7 kg	0,92 s	1,23 s	Normal
5.	18 Hours	35%	2,2 kg	0,86 s	1,06 s	Needs Cleaning
6.	20 Hours	30%	1,5 kg	0,90 s	1,08 s	Needs Cleaning
Average				0,91 s	1,18 s	

Based on the Condition Status Response Time data since the two sensors (HC-SR04 and Load Cell) detect waste, the average response time of the two sensors is less than 1 second or only around 0.91 seconds. For the response time of the trash bin condition status, if there is movement in the area of the two sensors, the condition of the trash bin will change and display the status of Normal, Needs Cleaning and Highly Needs Cleaning has an average time of 1.18 seconds. So based on the test results table above, it can be concluded that the sensor can read the height or load of the waste and display the weight of the waste on the application according to the sensor reading with different time intervals, then send a notification when the sensor reads the height or load and weight of the waste from the measurement results from the specified limit. The further the ultrasonic sensor reads the height of the waste, the less the contents of the trash bin, and vice versa, the closer the ultrasonic sensor reads the height of the waste, the waste is almost full. And the heavier the waste, the higher the kilogram of waste that is read. When reading the data of the two sensors, the status of the bin condition will change and the notification is successfully sent based on the fuzzy rules that have been applied with varying time intervals.

In the last test, the trash bin monitoring test was carried out by placing the trash bin prototype in 2 different locations, and starting on Monday, January 8, 2024 at 08.00 at the Faculty of Tomakaka University Mamuju and testing the tool for 6 days, what if the trash bin is placed in a public place where many people can throw waste into the trash bin that is placed, then every day the waste will be drained to test the tool again in an empty state for 6 days of trial to find out the work results of the waste monitoring tool. After several days of testing, the test results can be seen in table 7 below, where all bins are successfully monitored, and the system successfully sends notifications according to the fuzzy rules that have been applied so that it can be concluded that the system works well and according to its function.

Table 7. Trash Bin Testing

Testing Days-	Last Cleaning Time (LCT)	Trash Bin 1		Blynk Notification Status	Trash Bin 2		Blynk Notification Status
		Waste Load (WL)	Waste Weight (WW)		Waste Load (WL)	Waste Weight (WW)	
Day 1	5 Hours	12%	0,4 kg	Normal	18%	0,6 kg	Normal
Day 2	8 Hours	31%	2,6 kg	Needs Cleaning	25%	0,9 kg	Normal
Day 3	12 Hours	53%	1,3 kg	Needs Cleaning	43%	1,3 kg	Normal
Day 4	16 Hours	57%	2,7 kg	Highly Needs Cleaning	52%	2,1 kg	Highly Needs Cleaning
Day 5	20 Hours	53%	1,8 kg	Highly Needs Cleaning	39%	1,4 kg	Needs Cleaning
Day 6	24 Hours	42%	2,2 kg	Needs Cleaning	49%	2,6 kg	Highly Needs Cleaning

4. Conclusions

After the author has done the research, it can be concluded that the home waste monitoring system based on the Internet of Things using Fuzzy Logic is successfully designed using 4 modules/hardware, namely: NodeMCU ESP8266 as a microcontroller as a data processor and receiver, HC-SR04 Sensor as a module to read the height or load of waste, Load Cell Sensor as a module to detect the weight of waste, Blynk application displays indicators of waste load, waste weight and status of the condition of the trash bin based on the application of fuzzy rules, the system successfully sends notifications if the waste load indicator has reached >= 50% height >=2.5 kg and the last cleaning time >16 hours to the Blynk application with an average response time of sent notifications is <2.65 seconds. From the test results, it is found that the average margin of error of the two sensors is <10% with a sensor accuracy level of >90%, After testing the tool for 6 days it is concluded that the system works without problems and is ready to be implemented.

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