



Internet of Things Based on Waste Can Monitoring System to Detect Waste Can Capacity

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Abstract

Inefficient waste management and transportation can lead to excessive waste accumulation in temporary waste shelters and environmental pollution. Waste cleaning is generally carried out periodically, but the obstacle or challenge is when the fleet to carry out checks is limited. This reduces the performance of cleaners in cleaning garbage cans in different places to be slow or the cleaners cannot detect exactly where the garbage cans are full. One solution to overcome this problem is to apply *Internet of Things* (IoT) technology in the trash can monitoring system. The method used in this study is an experimental method. This research aims to design and develop an Internet of Things-based trash can monitoring system that is able to detect waste capacity in *real-time*. The system uses *ultrasonic sensors* to measure the level of fullness of the bin, a microcontroller as a data processor, and an IoT communication module to transmit information over *the web*. The data obtained is analyzed to provide automatic notifications to *the web* to the janitor when the bin is close to maximum or full capacity. The results of the measurement of the tool show that the system is able to accurately detect the condition of the bin and provide real-time status on the website based on the average results of the sensor readings.

Keywords: *Internet of Things, Ultrasonic sensors, Trash cans.*

1. Introduction

Waste is all the residues of human daily activities or natural processes in solid or semi-solid form in the form of organic or inorganic substances that are biodegradable or non-biodegradable that are considered useless and disposed of into the environment. Waste is an unavoidable and growing problem. Along with population growth and human activity, the amount of waste produced is increasing. If not handled properly, the resulting accumulation of waste will have various negative impacts, such as environmental pollution, urban aesthetic disturbances, the spread of diseases, and unpleasant odors.

The problem of waste has become more complex in urban areas due to the dense population and high economic activity. Inoptimal waste management can cause waste accumulation in various city districts, especially in temporary waste shelters (TPS). This happens due to the lack of an effective monitoring system, so cleaners are often late in transporting waste. Thus, garbage cans often experience fullness before the transportation schedule arrives, which causes environmental pollution and inconvenience for the surrounding community. The garbage will be transported according to the schedule that has been set. But what if the garbage can is full before the supposed transportation schedule, especially if the garbage transportation schedule is still longer than the set schedule, garbage will accumulate due to lack of checking the garbage can.

In Waingapu City, the problem of waste is a serious issue. Many garbage cans at various locations have been provided to facilitate the disposal of community waste. However, cleaners often face difficulties in knowing if the trash can is full or not. If the bin is full but not transported immediately, then the garbage will overflow and create unsanitary conditions. Currently, cleaners still check garbage cans regularly, which takes a lot of time and effort. On the other hand, the lack of a fleet in transporting waste is also the main problem. The fleet to transport garbage is only 10 but operates 7, while there are many scattered garbage shelters, and there are medium-sized garbage cans in every park in the city of Waingapu. This shortage of fleet results in the waste being transported slowly. In addition, delays in transporting waste from Temporary Shelters (TPS) to Final Disposal Sites (TPA) further worsen this condition.

Based on this background, the researcher proposed a research that aims to develop an *Internet of Things* (IoT)-based trash can monitoring system to detect the capacity of the trash can in *real-time*. *The Internet of Things* allows various devices to communicate and send data automatically over the internet network. The system uses *ultrasonic sensors* to measure the height of the garbage in the garbage can, then sends the information to a *web* server that can be accessed by the cleaner. By utilizing *Internet of Things* technology, a bin monitoring system can be developed to detect waste capacity in *real-time*. The implementation of an Internet of Things-based trash can monitoring system is expected to improve the efficiency of waste management by providing early warnings to cleaners when the trash cans are almost full through *the web*.

2. Literary Studies

2.1. Garbage

Waste is the waste of a product or item that is no longer used, but can still be recycled into valuable goods. Waste is also included in objects that lack and even have no use or economic value at all in the eyes of the public. Waste is a serious problem in environmental issues. According to Law number 18 of 2008 concerning waste management, waste is the remnant of human daily activities or natural processes in solid or semi-solid form in the form of organic or inorganic substances that are biodegradable or non-biodegradable which are considered to be no longer useful and disposed of into the environment [1].

2.2. Internet of Things

Internet of Things, or known as *IoT*, is an advanced technology that aims to extend and optimize the benefits of continuous internet connections, connecting objects around us to facilitate daily activities and improve the efficiency of human work. The Internet of things (IoT) is a rapidly evolving paradigm, where various electronic devices, sensors, and computing systems can connect and exchange data through the internet network [2].

The term "*Internet of Things*" consists of two main words, namely "*Internet*" which organizes and connects connectivity, and "*Things*" which means objects or devices. In simple terms, IoT involves "*Things*" that can be connected to each other to collect and transmit data to the internet. This data can also be accessed by other "*Things*". Certain objects can send data over a network wherever we are without human-to-human interaction or human-to-human interaction with computer devices.

2.3. Arduino IDE

IDE stands for *Integrated Development Environment*. This is referred to as an environment because through this software, *the Arduino* can be programmed to perform certain functions by using programming *syntax*. *Arduino* uses its own programming language similar to the C language. Before it was sold, *the Arduino microcontroller* IC had a *program called Bootloader installed*, which served as an intermediary between *the Arduino compiler* and *the microcontroller*.

2.4. Monitoring System

A monitoring system is a mechanism or technology used to observe, collect, and analyze data from a process or object *real-time*. This system aims to provide up-to-date information about the condition or performance of a system so as to enable more effective and efficient decision-making. Monitoring (Indonesian: monitoring) is monitoring that can be explained as awareness of what you want to know, high-level monitoring is carried out in order to make measurements over time that show movement towards or away from it. Monitoring is an activity aimed at providing information about the cause and effect of a policy that is being implemented [3].

2.5. Node MCU ESP 32 Microcontroller

Microcontroller is an IC consisting of CPU components, ROM, RAM, and output inputs. with the CPU, the microcontroller is in charge of carrying out processes based on the program that has been written. Microcontrollers are often referred to as mini computers by using low power so that the battery is not wasted [4]. The MCU node is an IoT-based motherboard that implements the Lua programming language. MCU nodes are open source so that developers or users can use *device* this and especially can also use the arduino sketch IDE [4]. At *microcontroller* This is already available WiFi module in the chip so it is very supportive to create an application system *Internet Of Things*. The main function of the ESP32 MCU Node is as the brain of the system that controls and processes data from sensors or actuators, as well as connecting it to Wi-Fi or Bluetooth networks for wireless data communication.

2.6. Breadboard

Breadboard is a board that functions to place and arrange devices or electronic components into a series of electronics without soldering. Breadboards have small sockets arranged in rows and columns. Inside there are metal connections that connect certain holes horizontally or vertically.

2.7. Sensor Ultrasonik HC-SR04

The HC-SR04 ultrasonic sensor is a sensor that works by reflecting sound waves. The sensor emits sound waves reflected by objects in front of it and then those sound waves are recaptured with time difference as a detection reference. The time difference between the sound waves produced and the sound waves received is proportional to the distance the object it reflects. The types of objects that can be observed by the sensor are liquid, solid and particle objects. The ultrasonic sensor can be easily connected to the microcontroller using one of the I/O pins [5].

This sensor works by emitting sound waves at very high frequencies and then detecting the reflection of those waves when they hit an object. The ultrasonic sensor consists of two main components, the Transmitter (*Transmitter*) This component produces ultrasonic sound waves. When the sensor is activated, the transmitter sends sound waves in the direction of the object to be detected, and the Receiver (*Receiver*) After the sound wave bounces back from the object, the receiver detects the reflected wave [6].

2.8. Cable Jumper

Cable *Jumper* It is an electrical cable that has an electrical pin at each end that allows the user to connect two components involving Arduino without soldering. The jumper cable is the component connector at the end of the cable. There are two types of connectors, namely male connectors and female connectors [7]. Jumper cables are commonly used on boards *breadboard* and tools *prototyping* so that it is easier to string together a network. Cable *Jumper* It works like a regular wire—conducting electrical current from one point to another. The inside of the cable is a conductor wire (usually copper) coated by a plastic insulator. When a wire is connected from one pin to another (e.g. from a digital pin in an Arduino to a breadboard), it creates a conductive path for electrical flow or digital signals.

3. Research Methods

Elevate Mbatakapidu Early Childhood Education School (PAUD) is one of the formal educational institutions for early childhood located in Mbatakapidu village, East Sumba Regency. Established on May 28, 2018 by the Charis Foundation. This school has received support from the government through the East Sumba Regency Education Office. The school is managed by 2 teachers with 17 students consisting of 11 male students and 6 female students for the 2024/2025 period.

The methods used as the study stage in This study are as follows:

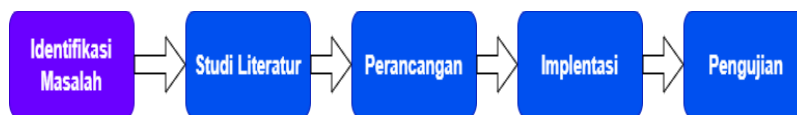


Fig. 1: Research Flow

Figure 1 is the research method used in this study. The research starts from identifying problems to identify the problem of waste that often accumulates or is full in temporary waste shelters. The accumulation of garbage in temporary garbage cans (TPS) is because it is difficult for cleaners to monitor waste capacity in *real-time*, then conduct literature studies through interviews, and analyze the devices needed to be hard and soft. Followed by system design which includes the selection of hardware components such as *microcontrollers* and *ultrasonic* sensors, as well as Wi-Fi wireless communication modules. Software design includes the development of a system to detect waste capacity and data processing through an IoT platform, then the implementation of the system by integrating hardware and *software*. Data from the sensors will be sent to a cloud server and displayed in a web-based monitoring dashboard. The trial phase is carried out to ensure that the system functions properly. The final stage of evaluation, test results to evaluate the effectiveness of the system and make reports and recommendations. If the system has not been successful in performing repairs and retesting.

3.1. Diagram Block

Block diagram design is a visual image used to illustrate the structure and function of an internet of things free bin monitoring system to detect the capacity of the bin.

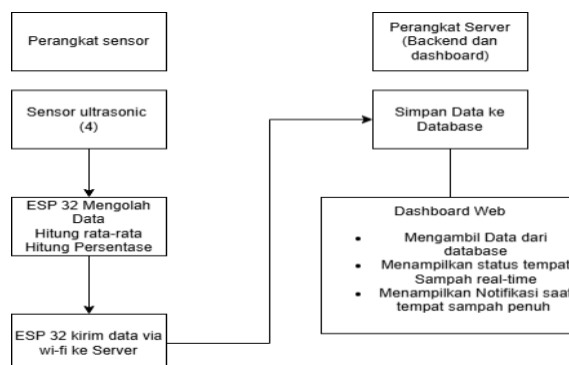


Fig. 2: Block Diagram

Figure 2. The above is a flowchart of an IoT-based trash can monitoring system. This system begins with a sensor device, namely four ultrasonic sensors, which are used to detect the distance of waste in the garbage can. Data from the sensor is then processed by the ESP32 microcontroller to calculate the average and percentage of the capacity of the bin. Once the data is processed, the ESP32 sends it over the Wi-Fi network to the server. On the server side, the data is stored in a database and displayed on the web dashboard. This web dashboard functions to retrieve data from the database, display the status of the capacity of the bins in real-time, and provide notifications when the bins are full.

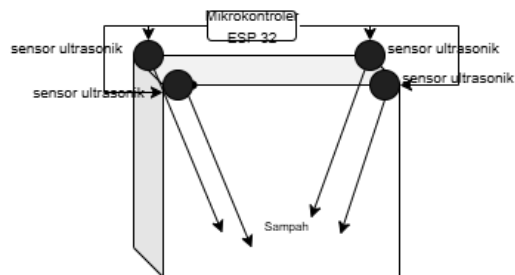


Fig. 3: Ultrasonic Sensor Placement Sketch

Figure 3. above shows a waste height measurement system that uses the ESP32 microcontroller as the main processing unit. The system is equipped with four ultrasonic sensors positioned at the top of the waste container. Two sensors are located on the front side and the other two on the back side, with the direction of the ultrasonic beam pointing downwards, towards the trash surface. This configuration allows the microcontroller to receive distance data from each sensor, which can then be used to estimate or monitor the height of the waste inside the container more precisely.

3.2. System Workflow

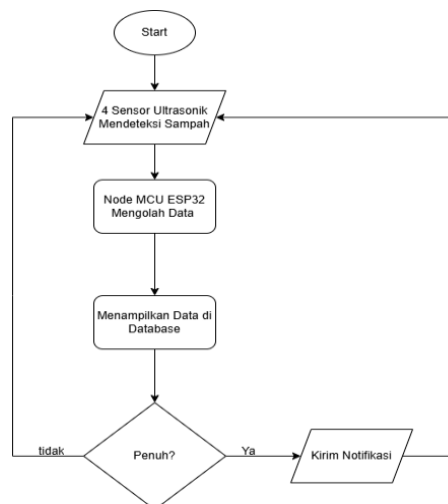


Fig. 4: System Workflow

Figure 4. above the diagram illustrates the communication flow and data processing from the bin sensor to the display on the web dashboard. The system uses ultrasonic sensors and ESP 32 microcontrollers to automatically detect the capacity of the bin, then transmit the data over the internet network to the database and finally visualize it in the form of a web view.

3.3 Diagram Skematic

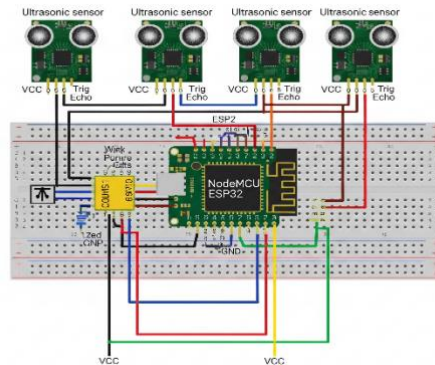


Fig 5: schematic digrams

Figure 6 is a *schematic* diagram of an internet of *things-based waste monitoring system* illustrating the relationship between the main components in the system designed to monitor the level of waste fullness in *real-time*. Through the integration of IoT components, the system provides solutions for more optimal and efficient waste management.

Table 1: Schematic Diagram Table of Tools

Sensor Ultrasonik 1 (HC-SR04)	VCC connected to 5V Arduino GND connected to GND Arduino	TRIG connected to pin digital D2 ECHO connected to pin digital D3
Sensor Ultrasonik 2 (HC-SR04)	VCC connect to 5V Arduino GND connected to GND Arduino	TRIG connected to pin digital D4 ECHO connected to pin digital D5
Sensor Ultrasonik 3 (HC-SR04)	VCC connect to 5V Arduino GND connected to GND Arduino	TRIG connected to pin digital D6 ECHO connected to pin digital D7
Sensor Ultrasonik 4 (HC-SR04)	VCC connect to 5V Arduino GND connected to GND Arduino	TRIG connected to pin digital D8 ECHO connected to pin digital D9

4. Results and Discussion

4.1. Analysis

Based on observations and interviews, the cleaners still check the garbage periodically in each scattered garbage bin, which requires a lot of time and effort. This shows a lack of efficiency in the waste collection process, as officers have to check each bin without knowing the exact level of fullness. As a solution to overcome this problem, the application of Internet of Things (IoT) technology in the form of a trash can monitoring system is easy. The system will be designed to detect the capacity of the bin automatically and in real-time. With accurate bin capacity information, cleaners no longer need to check periodically which is time-consuming. Officers can automatically see when the bin is almost full or already full, allowing them to plan a more efficient and responsive bin transport route

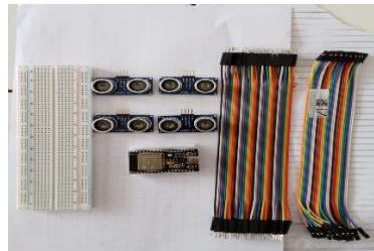


Fig. 6: Hardware Components

The picture above is the components of the tools used to implement in the trash. The components consist of 4 ultrasonic sensors, an ESP 32 microcontroller, a breadboard, and a jumper cable

4.2. Planning

The design of an IoT-based smart trash can includes designing tools, trash can models, programs to run components in IoT-based trash cans and displaying interfaces through the website to monitor the volume of waste in the trash can.

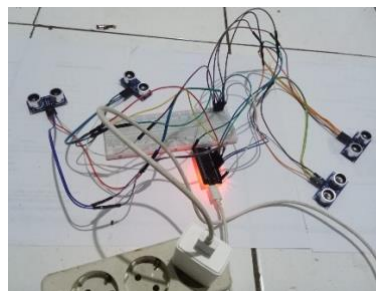


Fig. 7: Tool Range

The series of IoT tools in the image is a series of *internet of things* tools to detect waste capacity. The devices used are assembled and connected to each other for a *website-based bin capacity monitoring system* that uses four HC-SR04 ultrasonic sensors. Each ultrasonic sensor is positioned to detect the height of the waste inside the bin from four different sides. The sensors are connected to the ESP32 microcontroller via a breadboard and jumper cable, where the ESP32 serves as a control center that reads the distance data from each sensor. The read data can then be sent in real-time to platforms such as Firebase, or local websites via a WiFi connection. This system aims to monitor the level of bin fullness automatically and efficiently

4.3. Implementation

The process of implementing an Internet of Things (*IoT*)-based trash can monitoring system to detect pre-designed trash can capacity includes the development of programs in Arduino IDE, the display of the user interface using the website. The program was developed using the Arduino IDE to program the ESP 32 MCU Node microcontroller. The program regulates the reading of data from the ultrasonic sensor sensor to detect the volume of waste, process the data and send the measurement data to the web. In addition, for the reading of the type of waste, this program is also to set the reading of the ultrasonic sensor in detecting the volume of waste in the garbage can. The program also communicates with the website which is used as an interface for monitoring, which allows users to monitor the condition of the volume of waste in the trash in *real-time*



Fig. 8: Implementation of Tools in the bin container

The image above is a prototype of a trash can that has been implemented. This prototype is a physical form of the system that was designed, integrating all hardware components such as ultrasonic sensors, ESP 32 Microcontrollers, breadboards, jumper cables, and trash cans. This implementation is the most important stage to ensure that the design made can be realized in real terms and functions according to the research objectives

4.4. Testing

Conducting tests on the Internet of Things (IoT)-based waste monitoring system that has been designed aims to evaluate the performance of the system in detecting waste in real-time. This test focuses on detecting waste using ultrasonic sensors. The results of this test provide insight into the effectiveness and accuracy of the system in carrying out its functions.

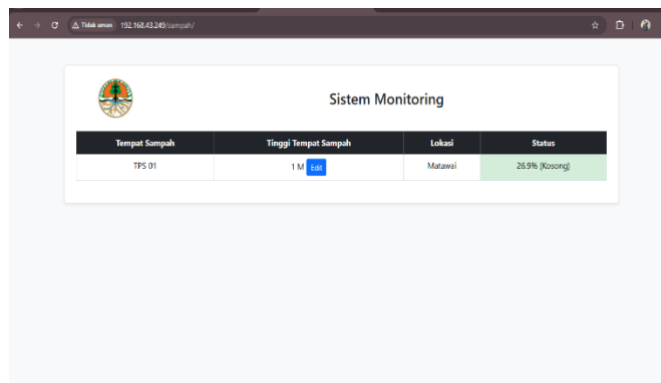


Fig. 9: Waste Monitoring System Website

In the image above, it is the result of monitoring on the system where the website displays the status of the filled garbage can according to the command of the control system that has been designed, so that monitoring can operate properly according to the program.

Table 2: Tool Test Results

Yes	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Average Capacity (Status)
1	11	3	9	5	26.9% (Kosong)
2	10	9	15	8	37.5% (Kosong)
3	18	17	16	15	40.50% (Kosong)
4	25	24	26	23	50.50% (Half)
5	35	32	33	37	58.50% (Half)
6	40	42	46	49	67.25% (Half)
7	50	48	53	57	75.50% (Half)
8	60	59	58	63	83.50% (Penuh)
9	74	76	75	73	89.50% (Penuh)
10	80	79	81	82	95.00% (Penuh)

The table above is the result of measurements using 4 ultrasonic sensors installed in one garbage can with a height of 1 meter. Each row shows the result of the distance reading (in cm) of each sensor to the garbage surface, which is then processed into a percentage of filled capacity. The capacity value is calculated based on the difference between the height of the bin and the sensor reading, where the smaller the reading distance, the more full the bin will be. The results of the tool's measurements show that the system is able to accurately detect the condition of the bin and provide a status in real-time based on the average sensor reading:

4. Conclusion

Based on the results of the analysis, the Internet of Things (IoT)-based trash can monitoring system is an innovative solution to overcome the problem of less efficient waste management. By utilizing ultrasonic sensors, microcontrollers such as the ESP32, and Firebase data communication, the system is able to detect and calculate waste capacity in real-time. The measurement data is displayed directly through the web dashboard, making it easier for cleaners to monitor the condition of the garbage can without having to do periodic checks. The implementation of this system has been proven to improve waste management efficiency, save time and effort, and support a clean and orderly environment. With accurate capacity information, the waste transportation schedule can be set more optimally, and measures to prevent waste accumulation can be carried out faster.

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