IoT-Based Smart Dustbin Prototype

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***Abstract* – Increasing population and consumption patterns affect the volume, type, and characteristics of waste which vary and increase periodically. This increment must be accompanied by the management of waste transportation so that the accumulation of waste can be prevented. Therefore, it is necessary to design a prototype of a smart dustbin condition monitoring tool that is capable of providing full information and notifying the collector in the form of the location of the IoT-based dustbin. The research method is a prototyping type to obtain a smart dustbin prototype and produces IoT-based smart dustbin hardware and software. Ultrasonic sensors are used to detect objects and measure the height of waste, loadcell sensor measure the weight of waste, and GPS is used to obtain the location of dustbin. NodeMCU ESP8266 processes sensor data and sends it to the user. The results showed that testing of the object detection hardware was able to open and close the dustbin automatically when there was an object at a distance of ≤50 cm. Detectors of height and weight of waste can measure the height and weight of waste with an error of 0.4% and 0.15% respectively. The results of software testing show that the tool succeeds in sending WhatsApp notification data when the waste height reaches 3 cm from the sensor or 4000-gram waste weight, with a Throughput measurement of 327.95 kbps, and takes 2.61 seconds to send a notification message of 69 bytes.**

***Keywords: smart dustbin, IoT, ultrasonic, loadcell, GPS*.**

I. INTRODUCTION

The phenomenon of waste accumulation that takes persistently and the irregular transportation of waste from temporary waste storage sites is still a problem in Makassar [1]. Problems that arise from conventional waste management can be overcome by utilizing the speed of accessing data using information and communication technology that is developing rapidly, one of which is the use of Internet of Things (IoT) technology. The IoT concept aims to connect objects continuously to the internet network for make it easier to use [2].

The application of IoT today has expanded to almost all areas of life, especially in terms of monitoring to obtain data in real-time remotely. The data that can be obtained also varies, as an example of its application to find out information on the use of electrical energy which can make it easier for PLN employees to monitor analog kWh meters [3]. Research [4] showed IoT-based monitoring devices were designed to obtain information related to voltage, electric current, and power measurements in real-time.

This system is surely beneficial, especially implemented to deal with a waste problem so that it can make it easier for cleaners or related parties to monitor the condition of dustbin. Much research has been done on making prototype dustbin with smart technology, one of which was research conducted by Suryaman [5]. Smart dustbin with height and weight detection technology are considered to have a good impact because they provide convenience in large-scale waste management. Research [6] resulted advantageous in identifying the weight and height of waste, monitored in mobile application platform. Here, IoT plays a role in sending data over the network without any interaction among humans, which can be utilized in building a remote dustbin monitoring system using sensors and microcontroller.

The existing system needs to be equipped with additional parameters, such as the need for a global positioning system (GPS) module which functions to track the whereabouts of full waste storage bins. GPS helps navigated location and time information in various weather conditions anywhere on the surface of the earth, in consideration of its reaches from a minimum of four GPS satellites [7]. The location parameter from the installed GPS module will provide information on the whereabouts of a full garbage collection site. In addition, knowing the presence of full dustbin will make it easier for the garbage collection fleet to go directly to the location, this will certainly have an impact on reducing the budget for fuel energy use in waste transportation activities. Thus, it is necessary to design a tool that can monitor whether a waste collection site is full or not and provide information to collectors to be transported immediately.

II. BASIC OF THEORY

A. Prototype

A prototype is a model or simulation of all aspects of the actual product to be developed, where this model must be able to represent the final product design. In system development, situations often occur where system users have defined the system or software goals in general even though they have not defined input, process, and output in detail [8]. Similarly, a prototype is a mental representation that serves as a cognitive reference point for the category. The most salient features of the prototype are the first features that come to mind when the category is mentioned [9].

B. Smart

Smart can be interpreted as an additional function on objects that can increase the value of the object's function as well as other objects, which can help human life. Smart has understanding as the ability to always adapt and adjust to the needs of its users. Hence, smart not only means intelligence but rather describes sustainability functions that can adapt to human needs [10].

Along with the artificial intelligence technology development, smart device is needed in processing and collecting information for IoT systems, where the microcontroller, sensors, actuators, and human beings are cooperated to achieve much more optimized service provision [11].

C. Dustbin

A dustbin is a container that collects waste or stores items that can or cannot be recycled repeatedly. Dustbin in Indonesian means rubbish bin. The existence of a dustbin aims to provide a place specifically to dispose of the residual products of human activity so that a positive impact on environmental hygiene and management of waste can be done more easily [12].

D. Internet of Things (IoT)

IoT in brief is a way to connect electronic devices to the internet and control it from all over the world for 24 hours without stopping. An object or in IoT terminology is called a connected thing with a computer or in practice is a microcontroller small size. This object is a tool that can emit a certain quantity, such as temperature sensors [13]. In the same way, IoT can be defined in its simplest scenario as a network that connects uniquely identifiable devices (or things to the internet, enabling them to collect, send, store, and receive data [14].

III. METHOD AND DESIGN

This study used the prototyping method, consisting of hardware and software design stages, followed by data collection to see the overall performance of the tool. Prototyping is known as a method that allowed users to build applications according to their needs [15]. The prototype built can detect the presence of objects in front of it, calculate the height and weight of the trash, and can perform the IoT function by sending notification messages about the condition of the dustbin to WhatsApp.

A. Hardware Design Block Diagram

Hardware circuit is divided into two separate parts, namely the Arduino Nano microcontroller circuit and the NodeMCU ESP8266. Figure 1. presents a tool's block diagram that will be implemented in making a prototype.

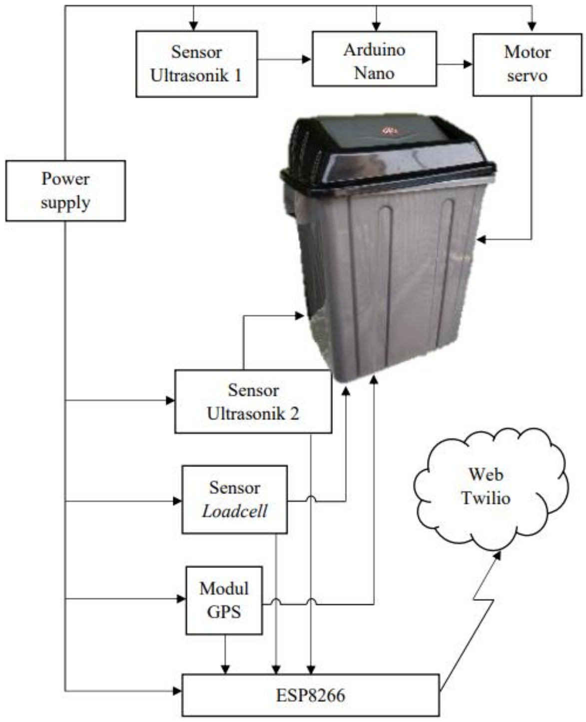

Figure 1. Tool's block diagram

B. Hardware Design

Hardware is composed of various components and modules with their respective functions. The object presence detection circuit consists of an Arduino Nano as a controlling microcontroller and processes data from the HC-SR04 ultrasonic sensor and outputs it in the form of a servo motor rotation. Figure 2 shows the object detector circuit.

The circuit in Figure 3 consists of the HC-SR04 ultrasonic sensor to measure the distance of waste from the sensor, the loadcell sensor, the HX711 module to measure the weight of the waste, the Ublox Neo 6 MV2 GPS module to track the location of dustbin. The microcontroller used is NodeMCU ESP8266, where this microcontroller can connect to a WiFi network, thus it can transmit data via the internet.

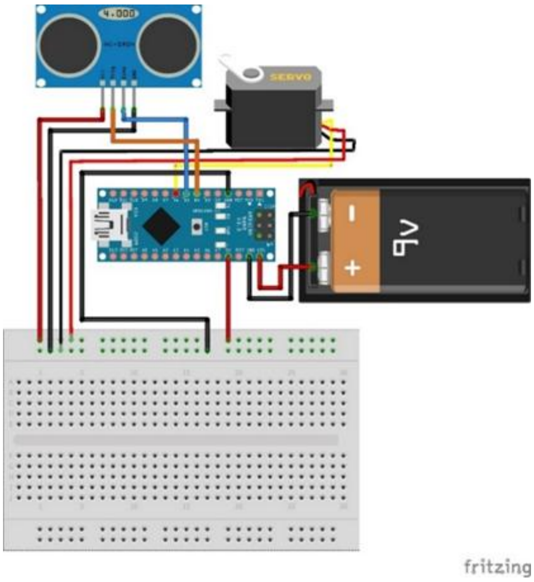

Figure 2. The object detector circuit

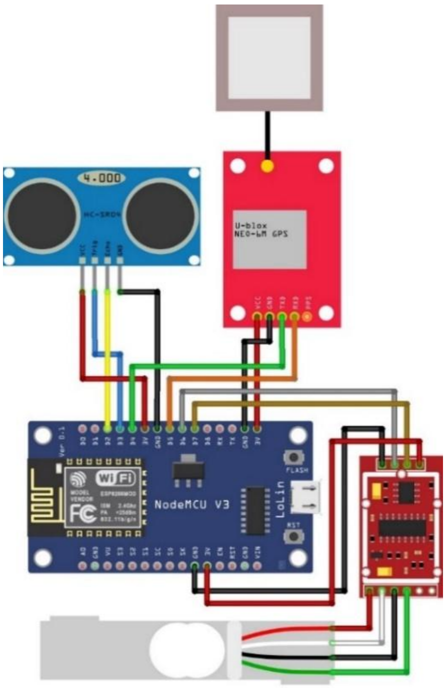

Figure 3. A series of detectors for the height of the waste, the weight of the waste, and the location of the dustbin

The volume of waste will be calculated by ultrasonic sensors and load cell sensors inside the dustbin to estimate the weight and height of the waste. When the height of the waste has reached a value less than equal to (≤) 3 cm or the weight of the waste has reached a weight greater than equal to (≥) 4000 grams, then the next process is the GPS module sending the location point where the dustbin is which is forwarded to the user's WhatsApp application via Twilio Web.

C. Software Design

The design of the program to operate the hardware according to the scheme that has been prepared is carried out using the Arduino IDE, written according to the Arduino programming language, namely the C++ language. The program that has been written through the *compiling* process is then uploaded to the hardware as of the device can work according to the design plan.

IV. RESULTS AND DISCUSSION

A. Prototype Design Display

Figure 4 displays the results of the overall smart dustbin prototype design on the planned designs.

Figure 4. Smart dustbin prototype

B. Hardware Testing Results

- Detect the presence of objects

The test procedure will see the ability of the HC-SR04 ultrasonic sensor to reach objects in front of the dustbin. The following is a picture of the test diagram. Data from the object presence detection test results are presented in Table 1 as follows.

Table 1. Test Results for Opening Dustbin Lid

No	Defined distance (cm)	Testing distance (cm)	Information
1		10	Open
2		20	Open
3		30	Open
4		40	Open
5	≤50	50	Open
6		60	Closed
7		150	Closed
8		200	Closed
9		250	Closed
10		300	Closed

From the test results 10 times using different distances, it can be seen that opening the dustbin lid using the SG90 servo motor shows that it can open automatically when there is an object in front of it with a predetermined distance of ≤50 cm and closes again when there is no object in front of it. Setting a distance of ≤50 cm is considered the most appropriate so that the sensor does not process input that is not supposed to, for example, objects (people) passing by.

- Garbage level detector

The garbage height detection test aims to see the accuracy of measuring the height of the garbage from the HC-SR04 ultrasonic sensor compared to a ruler measuring the capacity of the contents of the dustbin. Data from the trash height detection test results (sensor distance to the trash) and the percentage of this error value are presented in Table 2.

Table 2. Results of The Garbage Height Detection Test

No	Ultrasonic sensor HC-SR04 (cm)	Ruler measuring tool (cm)	Error (%)
1	20.0	20.0	0
2	8.0	8.0	0
3	13.8	13.9	0.7
4	15.4	15.4	0
5	15.7	15.7	0
6	11.0	10.9	0.9
7	15.7	15.7	0
8	14.6	14.5	0.7
9	20.7	20.6	0.5
10	17.0	17.2	1.2
Average			**0.4%**

The maximum waste height value of the dustbin is in full condition and is set at a distance of 3 cm from the sensor. From the results of the calculation of the percentage error, the smallest error value is 0% and the largest error value is 1.2% with a difference of 0.2 cm in the calculation results. The average percentage of error from ten times testing is 0.4%, so it can be concluded that the HC-SR04 ultrasonic sensor is quite accurate and can be used to detect the height of garbage.

- Garbage weight detector

The waste weight detection test aims to see the accuracy of measuring the weight of waste from the loadcell sensor and the HX711 module compared to a digital scale measuring instrument. The following is a block diagram of the waste weight detection test. Data from the test results for detecting the weight of waste and the percentage of this error value are presented in Table 3 below.

Table 3. Results of the Garbage Weight Detection Test

No	*load cell* sensor (gr)	Digital scales (gr)	Error (%)
1	345	345	0
2	244	243	0.4
3	450	450	0
4	355	353	0.6
5	596	596	0
6	486	486	0
7	707	708	0.1
8	192	192	0
9	170	170	0
10	888	885	0.3
Average			**0.15 %**

The maximum waste weight value of the dustbin in full condition is set at 4000 grams. From the results of calculating the percentage of error, the smallest error value is 0% and the largest error value is 0.6% with a difference of 2 grams in the calculation results. The average percentage of error from the ten tests was 0.15%, thus it can be concluded that the loadcell sensor and the HX711 module are quite accurate and can be used to detect the weight of waste.

C. Software Testing Results

Software testing focuses on the process of sending waste height and weight data obtained from the HC-SR04 ultrasonic sensor and loadcell sensor, where when the waste height (3 cm from the HC-SR04 ultrasonic sensor) and waste weight (4000 gram) values are met, then a location notification message will appear obtained from the GPS module to the user's WhatsApp. Therefore, to test the performance of sending data by NodeMCU ESP8266 via the network to WhatsApp, parameter measurements are used Throughput using Wireshark software.

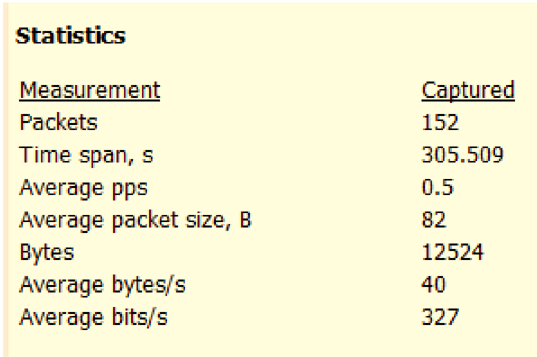

Figure 5. Capture file properties testing

This test was carried out to determine the quality of the NodeMCU ESP8266 network connection, thus it can transmit data to the user's WhatsApp. Figure 6 shows the display of the results of the capture file properties testing on Wireshark.

Figure 5. contains data that can be used to determine throughput values including bytes of 12524, and a time span of 305,509 seconds. The test was carried out for 5 minutes to see the quality of the Throughput parameter. To obtain the Throughput value, the calculation is the number of bytes divided by the time span period. [6]. Based on the Wireshark data, the following is the throughput calculation result.

The calculation results using equation above produce a Throughput of 327.95 kbps. Through this calculation, the quality of the data communication network is determined, especially the internet network, so that it can show the slow speed of data transmission over an internet network. The results of sending dustbin location data to WhatsApp users in the form of notifications can be seen in Figure 7 as follows.

Figure 6. WhatsApp notification messages

The size of the notification data sent via the NodeMCU ESP8266 to Web Twilio is known to be 69 bytes. The notification data is in the form of text that reads "Tempat Sampah Penuh di: www.google.com/maps/place/-5.134230,119.447608".

D. Discussion

The detection of the existence of objects designed using the HC-SR04 ultrasonic sensor and the SG90 servo motor as the actuator shows that it can open the lid of the dustbin automatically when there is an object in front of it with a predetermined distance of less than 50 cm. At a distance of more than 50 cm, the servo motor will not move the dustbin lid.

In the garbage height detection test which was carried out 10 times at different distances from the sensor to the garbage, it showed that the sensor measurement was quite accurate and could work well. The maximum height value for trash or when the dustbin is full is set at a distance of 3 cm from the sensor, this is based on the distance measurement capability range of the HC-SR04 ultrasonic sensor which is between 2 cm for the minimum distance, and 400 cm for the maximum distance. From the results of the calculation of the percentage error, the smallest error value is 0% and the largest error value is 1.2% with a difference of 0.2 cm in the calculation results. The average percentage of error from ten times testing is 0.4%, so it can be concluded that the HC-SR04 ultrasonic sensor is quite accurate and can be used to detect the height of garbage.

Tests for measuring the weight of waste using the loadcell sensor and the HX711 module show successful measurements as evidenced by the differences in sensor measurements and a digital scale measuring devices that are not much different. The measurement results of the largest percentage of measurement error values by the loadcell sensor and HX711 module are 0.6% with an average percentage error of 10 times of testing, namely 0.1 - 5 %. The maximum waste weight value of the dustbin in full condition is set at 4000 grams. The load cell sensor specifications used are capable of measuring weights up to a maximum of 5000 grams. Therefore as not to overload the loadcell sensor with excessive weight which can damage the sensor, the maximum waste weight parameter that can be sent as a full garbage notification is set at 4000 grams.

The built software design can send full trash notifications from ESP8266 to Twilio Web. After testing the Throughput parameter for 5 minutes, the Throughput value is 327.95 kbps. To be able to send a 69-byte WhatsApp notification via Web Twilio takes approximately 2.61 seconds. The notification message on the user's WhatsApp was successfully delivered but with delays in data transmission.

V. Conclusion

The design of the prototype was successfully carried out through testing resulting the dustbin lid can be opened automatically when there is an object approaching at a maximum distance of 50 cm. The test method utilizes different distances, ranging from 10cm to 50cm which indicates the dustbin lid is open, while a distance of 60cm to 300cm shows the lid is closed.

The height detection test was carried out 10 times by giving a random number of distances as input to the sensor. The test resulted in a measurement error value by the height detectors compared to a measuring instrument was 0.4%. The loadcell sensor used to detect the weight of the waste generates a slight error value of 0.15%. This error value is obtained from the results of measuring the weight of the waste carried out 10 times. The measurement results using the loadcell sensor are not much different from the measurement results using digital scales.

The smart dustbin software design shows it functions well in sending a full dustbin notification message containing the latitude and longitude values of the dustbin location via the Twilio Web to WhatApp.

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