Design a Smart Trash Using Fuzzy Logic Algorithm

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ABSTRACT
Collection carried out by waste officers cannot be carried out effectively. This reduces the performance of garbage officers at the trash bins at different points. Smart trash cans can eliminate the needed trash to maximize their work. This study designed a trash bin monitoring system using ultrasonic sensors and weight sensors. The system uses fuzzy logic as a controller for the trash can lid. In this study, the maximum distance that the ultrasonic sensor reads in the trash is 30 cm, the shortest distance is 0 cm, while the weight sensor reads 0 Kg to 40 Kg according to the capacity of the trash can. Data processing uses ESP32, which functions as a medium for processing and sending data. From the tests carried out, the accuracy of the ultrasonic sensor HC-SR04 has a deviation of 20%. At the same time, the deviation of the Load Cell weight sensor is 1%. The action of opening and closing the trash cans is determined using the fuzzy logic method with 100%.

Keywords: *Fuzzy Logic, ESP32, Smart trash cans, Ultrasonic Sensor, Load Cell Sensor*

1. INTRODUCTION

Waste segregation is necessary for a sustainable society. The current recycling process requires recycling facilities to sort the waste by hand and use a series of large filters to separate objects more clearly. Consumers can also be confused about determining the correct way to dispose of the various materials used in packaging. Our motivation is to find automated methods for sorting waste. This can make processing plants more efficient and help reduce waste, as employees don't always sort everything with 100% accuracy. This will have a positive environmental effect and a beneficial economic effect[1].

Waste has become a national and even international problem, so its management must be done collectively, comprehensively and integrated. In managing waste properly, knowledge about the types of waste is needed [2]. In supporting the "Sort Garbage From Home" program launched by the Ministry of Environment and Forestry in 2019, the government must provide understanding and education to the public about waste[3]. This education is needed because Indonesia is the second largest producer of plastic waste globally. During the Covid-19 pandemic, the waste generated tends to be more than usual. Masks, face shields, and other medical waste, most of which can only be used once. Increased online shopping and food delivery activities have also contributed to the increase in waste generated during this pandemic. So, we need a solution to monitor the garbage [4].

Waste segregation is significant, but supervision and people responsible for picking and cleaning trash cans in several locations are very necessary (Airlangga, n.d.; Citra, 2020; Putrawan et al., 2021; Putri Nourma Budiarti et al., 2018; Mahyudin, 2017). However, until now monitoring or supervision of trash bins is still done manually, so that officers must routinely pick up trash even though the trash can has no contents or even the trash can has exceeded the capacity of the place [6]–[8]. This will take a long time and will reduce the performance of the waste officer in carrying out his work, besides that it will also require greater costs and is very ineffective. On the other hand, one of the factors that causes people to litter is the condition of the trash bins being dirty and also due to the accumulation of garbage, which makes some people reluctant to dispose of the trash in its place. With the rapid development of technology, this problem should have been resolved [9]–[11].

The prototype of a smart trash can that can monitor the trash can has been pre-built. The protocol used in IoT is MQTT (Message Queuing Telemetry Transport), which is a lightweight message designed for

devices with limited resources. With the IoT concept, monitoring of trash bins is carried out using several sensors such as the use of a weight sensor (load cell) as a waste weight detection, the HX711 module as a load cell weight value conversion and a magnetic switch sensor to determine the opening or closing of the trash bin which is assembled with a microcontroller [12], [13].

In another study, a real-time monitoring system for trash bins was designed and sent notifications to garbage collectors. The system is based on IoT and Android, integrated with Firebase Realtime Database and Firebase Cloud Messaging. The system uses the HC-SR04 sensor to detect the volume of waste. The average notification time received by the android application is 0.6 seconds from the research conducted. This system is able to measure the volume of waste in real-time and remember the time of the last waste collection. Determination of waste collection actions using the fuzzy logic method [12].

Other studies also conducted research on the development of Smart Environment applications to help control the cleanliness of trash bins in the community environment using IoT technology. Data acquisition via IoT uses the Message Queuing Telemetry Transport (MQTT) protocol, the HY-SRF05 ultrasonic distance measuring sensor, Arduino UNO, and the ESP8266 IoT module. This study observes system performance test parameters in the form of delay, packet loss, and throughput values during data transmission [14].

Other studies have built a telemetry system for monitoring waste in the reservoir and also to provide education to the public so as not to litter. A warning SMS will be sent by the system when the measured waste volume is full using the ultrasonic proximity sensor HC-SR04. The results of testing the performance of the sensor when measuring the distance of the object compared to the actual distance obtained a maximum error value of 0.25%. The sensor can work well at a distance of 5 cm to 400 cm. The expected result from the design of the telemetry system for monitoring waste in the reservoir is the optimization of the work of the cleaners in transporting waste without the need to check repeatedly, because information on the volume of the garbage bin will be sent directly via Short Message Service (SMS) [8]. From the results of the literature study, the author makes a design for a smart sage place using an algorithm fuzzy logic.

2. METHODS

In this study using an experimental research approach. Experimental research method is a research method to test whether the variables in the experiment are effective or not. To test whether it is effective or not, control variables must be used. Experimental research is conducted to test the hypothesis that has been formulated strictly. Experimental research aims to investigate possible causality by applying one or more treatment conditions and comparing the results with one or more groups [15]–[17].

This trash can uses an Ultrasonic sensor to detect the height and a Load cell-based weight sensor to weigh the trash in the trash can. The ESP32 will process the input from the ultrasonic sensor and the weight sensor. Then ESP32 detects the height of the trash bin and the weight of the trash if it's not full, then ESP32 will instruct the actuator to open the trash can cover and vice versa. The height of the litter and the weight of the litter may vary. Therefore, a fuzzification process is needed to determine the status of the trash bin in opening the lid and closing the trash can based on the height of the trash and the weight of the trash. Fuzzy logic allows membership values between 0 and 1, grey level, black and white, and linguistic form [18], [19].

Fuzzy logic was developed from fuzzy set theory. A fuzzy set is a grouping of things based on a language variable (linguistic variable) expressed in a membership function in the universe U. Membership of a value in the set is expressed by the degree of the membership whose value is between 0.0 to 1.0. Its membership value indicates that an item is not only true or false. A value of 0 indicates false, a value of 1 indicates true, and there are still values that lie between true and false [20].

A. System Design

The system design or general description of the system made in this study includes three main parts: hardware, software, and fuzzy design. The waste monitoring system is designed with a trash can lid that

can be opened automatically according to sensor readings. Then the process of opening the garbage cover uses the fuzzy logic method.

System Software Design

This research carries out several interrelated processes in the form of research steps. Software development is based on identifying sensor readings, and then a rule is made on the MATLAB software. The rules on the fuzzification are used as a reference in making the main program to open and close the trash can.

In designing the software, the Arduino IDE software is used to embed the program on the ESP32 board. The Arduino IDE itself uses the Arduino programming language based on the simplified C++ programming language.

In this study, ESP32 is used as a sensor value reader and converted to the desired unit. The weight sensor reading will be converted to grams, and then the ultrasonic sensor reading will be converted to centimetres.

B. Electronic System Design

In electronic design, Fritzing software is used to create wiring diagrams to make it easier for researchers to assemble components to reduce connection errors between components. The Node MCU V3 electronic development board based on the ESP32 microcontroller was used in this study. In addition, other components such as Load cell (weight sensor), MQ135 (gas sensor), and Ultrasonic Sensor HC-SR04 (ultrasonic sensor) are also used. The component wiring diagram can be seen in Figure 1. In Figure 1, the weight sensor is connected to the HX711 module as an amplifier and a calibrator for weight measurement before being connected to the RX/TX pin on the GPIO ESP32. The ultrasonic sensor on the trigger pin is connected to digital pin 5, and the echo pin is connected to digital pin 6. The pin on the gas sensor is connected to analog pin 0 ESP32.

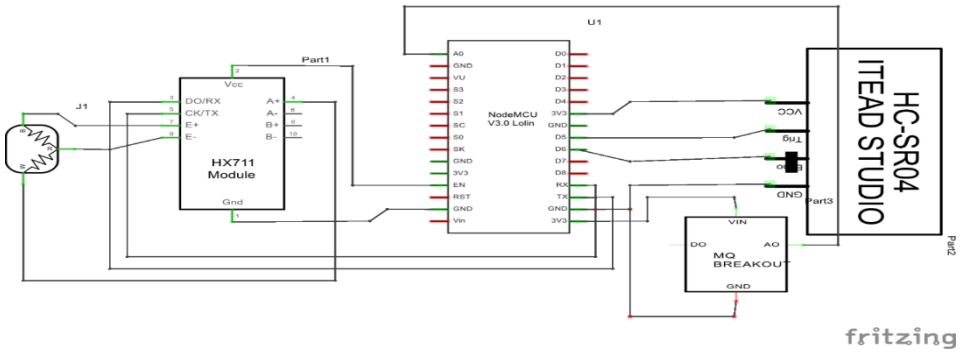

Figure 1 Electronic Design

The trash can made in this study uses an ultrasonic sensor HC-SR04 series to detect the height of the trash can load, and the weight sensor uses a load cell with IC HX711. The ESP32 microcontroller will process the data from the HC-SR04 sensor and Load Cell to detect the height of the trash can and the weight of the trash. So that when the received garbage data is full, the ESP32 will instruct the actuator to open or close the trash can.

D. Fuzzy Logic Design

The application of fuzzy logic is carried out in determining the status of the trash bin based on the height of the garbage load and the varying weight of the garbage, which determines what action the trash can officer should take.

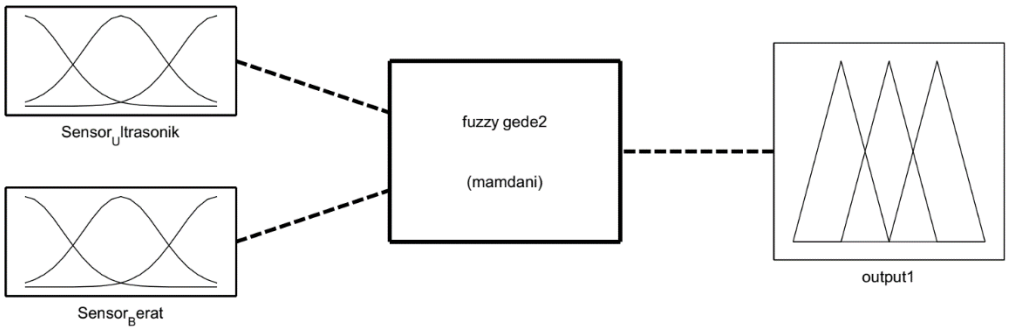

Figure 2 Mamdani's Fuzzy Logic Design

From Figure 2, the varying values will be used as two fuzzy input variables, including:

1. Ultrasonic Sensor: ie data generated by the ultrasonic sensor designed in the ESP32.
2. Weight Sensor: the data generated by the Load Cell sensor.

A transformation from an input to an output in a fuzzy domain is used to process the data from these two variables. The ultrasonic sensor input variable uses the Empty, Medium, Full and Very Full scale and the weight sensor input variable uses the Empty, Heavy and Very Heavy scale because if you use it in centimeters (cm) and kilograms, it will confuse the trash can staff because of the size of the place. different trash.

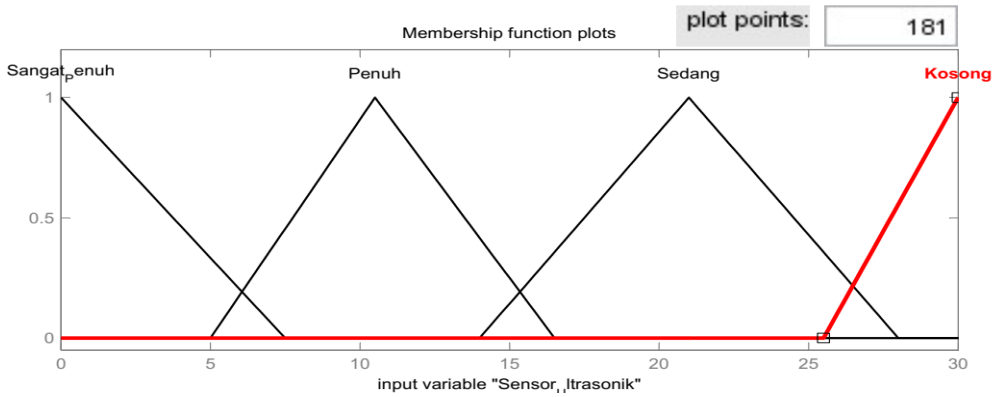

Figure 3 Membership Input Ultrasonic Sensor

The ultrasonic sensor variable in Figure 3 is divided into four sets, namely Empty, Medium, Full, and Very Full. These four sets are based on the height of the trash in the trash can. This number form is used to facilitate the creation of fuzzification rules.

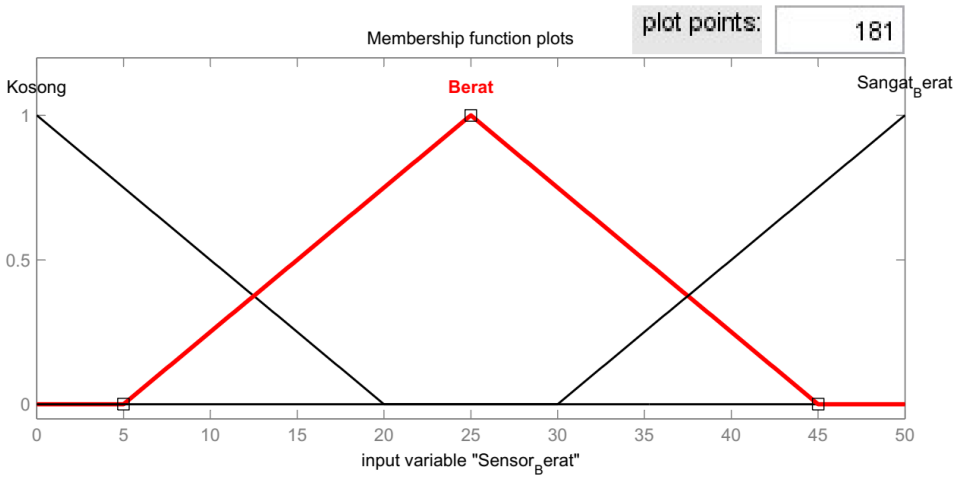

Figure 4 Membership Input Weight Sensor

The ultrasonic sensor membership variable in Figure 4 is divided into three sets, namely Empty [-20 0 20], Heavy [5 25 45], and Very Heavy [30 50 70]. These three sets are based on Kilogram measurements. This set is based on the weight of the garbage in the trash.

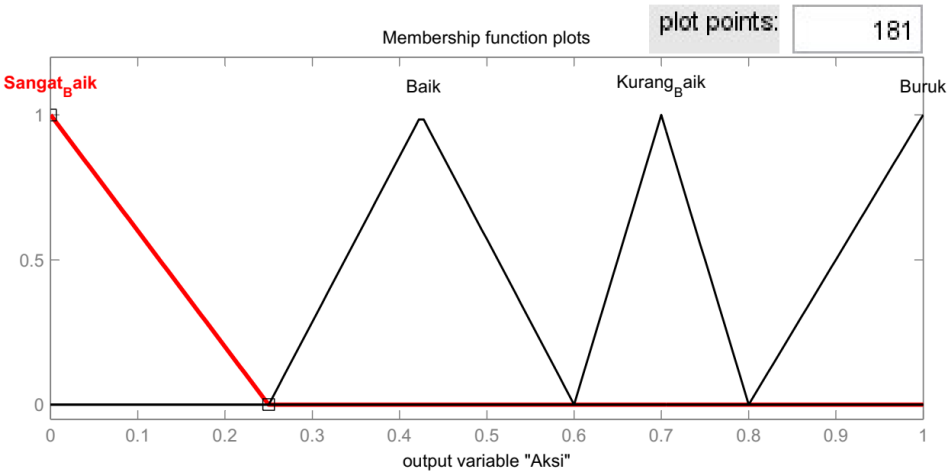

Figure 5 Fuzzification Output

The Action variable shown in Figure 5 is divided into four sets: Very Good, Good, Less Good, and Bad. These four groups are actions taken by garbage cleaning officers. Of the four sets in Figure 4, the variables sent to ESP32 for processing are only Good and Very Bad variables because these two variables will be used for commands to open or close the trash can.

Figure 6 Fuzzification Rules

In applying the system, the author must follow the rules that have been made previously. These rules will be used as a reference in coding the program. From Figure 6, it can be explained that if the ultrasonic sensor reads a value between 25 - 30 cm and the weight sensor reads a weight between 15 - 20 Kg, it will take action to open the trash can cover. If the ultrasonic sensor reads a value between 15-20 cm, but the weight sensor reads a weight of more than 20 Kg, the trash can will remain open. Meanwhile, if the ultrasonic sensor reads a value of less than 10 cm and the weight sensor reads a weight of more than 25 Kg, the trash can will be closed, and it is no longer allowed to throw garbage in the trash can.

The simulation on the MATLAB software shows in Figure 7 that after the rule is entered into the system, it will produce a surface graph that shows the distribution of membership values for each fuzzification element. From the picture, it can be seen that the value of the Very Good trash has the most minor of least area. This is because the rule only allows the trash can to be in good condition if the trash can is empty, as shown by a small ultrasonic sensor reading and a heavy sensor reading.

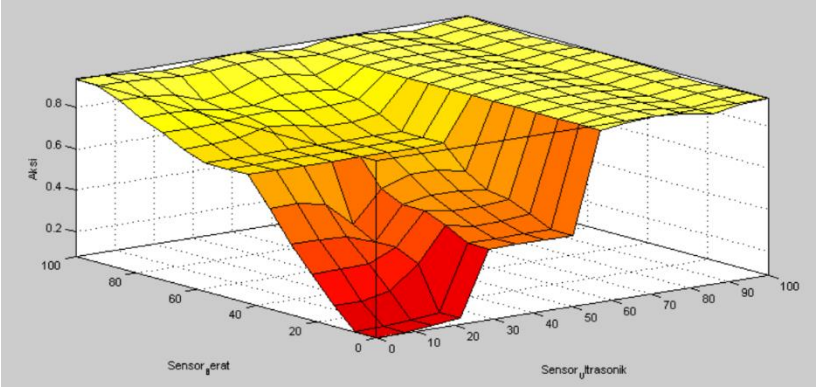

Figure 7 Simulation Results in Matlab

3. RESULTS AND DISCUSSION

Next is the performance test on the Load Cell weight sensor. This study used 10 types of waste placed on the trash can. Trash cans have a volume load of 30 L or approximately 30 to 40 kg. In calculating the weight of the trash bin, it is necessary to calibrate the loadcell beforehand. Loadcell calibration requires HX711 IC as an amplifier. The results of data collection that have been calibrated are as in Table 1.

Table 1 Ultrasonic Sensor Test

Sensor Test	Ruler	Ultrasound Sensor
1	7	7
2	10	10
3	13	13
4	16	15
5	19	18
6	21	21
7	23	23
8	26	25
9	29	28
10	30	30.1

The test results were based on Table 1 which was carried out on 10 data collection times. From these tests, similar results were obtained, there are 194 and 190. The average measurement result with a ruler was 19.4, while the average measurement result with the ultrasonic sensor was 19. So from these two values, the percentage error of measurements made using the sensor could be calculated. Ultrasonic as follows.

The data in Table 2 is used as a simulation to determine the weight of the trash can. From the data calculated based on the difference between the scales on the market using a weight sensor, the accuracy of

the load cell weight is obtained which has a weight difference value ranging from 0.01 kg to 0.03 kg. With an average difference of 0.0096 kg. Load Cell can calculate mass with very high accuracy. To simulate the opening and closing of the trash can, fuzzy logic is needed that has been previously designed.

Table 2 Testing the Load Cell Weight Sensor

No	Garbage Type	Weighing Scales (Kg)	Weight on Sensor (Kg)	Difference (Kg)
1	Rice Trash	2.00	2.01	0.01
2	Fruit Trash	1.24	1.21	0.03
3	Vegetable Garbage	1.31	1.30	0.01
4	Bottle Trash	1.0	1.01	0.01
5	Plastic waste	0.018	0.017	0.01
6	Glass Trash	0.20	0.20	0
7	Metal Trash	1.45	1.46	0.01
8	Paper Trash	0.955	0.956	0.01
9	PCB Trash	0.25	0.25	0
10	Mixed Garbage	0.30	0.31	0.01

The smart trash can made in this study is designed to detect objects if the object is in an area of 0 – 30 cm and with a weight between 0 – 40 Kg. In Table 3, it can be seen the response made by the ultrasonic sensor HCSR04 and the weight sensor. For a distance between 20 cm to 30 cm and the weight, the sensor reads between 0 - 25 Kg, the lid of the trash can will open and if the weight of the garbage has exceeded 25 Kg and the object distance is less than 10 cm, the lid of the trash can will be silent and will not open. However, if the object distance is between 0 cm – 10 cm but the weight sensor shows less than 5 Kg, the trash bin will remain closed until the trash can is cleaned.

Table 3 Observation Results of the Smart Trash System

No	Object Distance (cm)	Weight Sensor (Kg)	Results
1	30	0	Cover Open (Very Good)
2	30	5	Cover Open (Very Good
3	27	7	Cover Open (Good)
4	25	10	Cover Open (Good)
5	23	12	Cover Open (Good)
6	20	15	Cover Open (Good)
7	17	17	Cover Open (Not Good)
8	15	20	Cover Open (Not Good)
9	12	23	Cover Open (Not Good)
10	10	25	Cover Open (Not Good)
11	7	27	Cover Not Open (Bad)
12	5	30	Cover Not Open (Bad)
13	3	32	Cover Not Open (Bad)
14	0	35	Cover Not Open (Bad)
15	0	40	Cover Not Open (Bad)

4. CONCLUSION

Based on the conclusion of the discussion of the research that has been done, it is concluded that the accuracy of the fuzzy logic algorithm in determining the action of opening and closing the trash can has a level of 100% so that the expected action is following the system.

From the tests made, the accuracy of the ultrasonic sensor HC-SR04 has a deviation of 20%. At the same time, the deviation of the Load Cell weight sensor is 1%. The implication of this research is to provide convenience for garbage officers in maximizing effective cleaning of trash bins and reducing the accumulation of trash that occurs.

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