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GARBAGE COLLECTOR ROBOT (GACOBOT) DESIGN FOR DRY WASTE DISTRIBUTION

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Abstract. GACOBOT is a garbage collection robot that is an integration of mobile robot systems and non-mobile robots, namely mobile robots like-a-car robot systems and robotic manipulators as garbage grabber systems. The GACOBOT system also integrates ultrasonic sensors and navigation systems as GACOBOT support systems, the garbage collection process has succeeded in the type of egg waste and bottle junk. The garbage collection process by conditioning the front ultrasonic sensor, then the grabber adjusts the trash and puts it into a garbage container while the robot is mounted by the robot. GACOBOT has been able to take garbage with iterations 40 times with 2 forms of garbage.

1. Introduction

Environmental hygiene is a must in social life, humans as living things need food to survive, there are natural and processed (synthesis) human sources of food. Every food ingredient usually leaves waste, this waste is called household waste, the handling of household waste is a common obligation in society, and neglected waste can cause natural disasters. For example the accumulation of household waste can cause flooding and become the nesting sources of disease.

The distribution of less periodic household waste is one of the causes of the accumulation of waste. Lack of human awareness in the distribution of household waste that causes natural disasters. Therefore a system or institution for distributing household waste is needed, such as general cleaning staff, which every day takes and distributes household waste to public landfills, human limitations in terms of health is one of the obstacles to the regular distribution of waste. To handle such case, a system is needed that can replace the role of humans in the distribution of household waste.

Robot is a tool that can alleviate human work, the design of robots that can distribute waste at one place to another can overcome the accumulation of household waste. Robot systems that are expected to carry certain loads and carry them, from the case of car-like robots or mobile robots that have a 4-piece drive system are ideal for lifting weights in a balanced manner.

Nowadays mobile robot technology has undergone very rapid development. Many mobile robot technology applications are used in everyday life. Such as room cleaning robots [1], bomb squad [2], intelligent wheelchairs [3], and freight forwarders in factories or hospitals [4]. A mobile robot requires a navigation system so that it can move from one place to another [5]. Smart moving robots of course must be able to recognize the situation.

2. Study Literature

2.1. Autonomous Mobile Robot
Autonomous mobile robots have the ability to move on their own without human help. But in actual circumstances autonomous mobile robots are the result of coordination between human guidance implanted in robots in the form of programs and detection of environmental patterns using sensors that produce movement performance [6]. One example of an existing autonomous mobile robot can be seen in Figure 1.

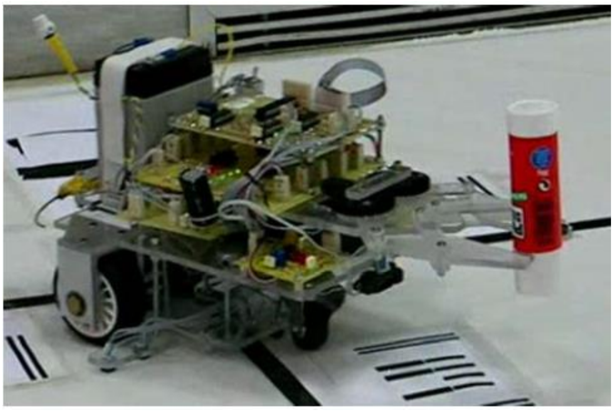

Figure 1. Autonomous Robot "Teseo" [7]

The ability possessed by autonomous movable robots is the result of coordination of several behaviours, namely wandering, avoiding obstacles (obstacle avoidance), looking for targets (target search) and finding targets [6]. Wandering behaviour is the ability of robots to get around in an unknown environment. Obstacle avoidance behaviour is a basic ability that a robot must have in order not to crash and can move freely around the environment.

In addition to the two abilities previously explained, the target search behaviour and target find behaviour are additional abilities possessed by the robot with a specific purpose, namely to find the desired target (goal) and stop in front of the target. All these mutually coordinating capabilities have a function that must be fulfilled, namely the introduction of environmental patterns.

2.2. Manipulator Robot
Manipulator robot is a robot that can manipulate certain objects that are usually arm-robotic, which is a combination of certain joints. Robotic manipulators have several basic concepts to move and towards certain objects such as direct kinematics, inverse kinematics, trajectory control [8], as shown in Figure 2.

Figure 2. Manipulator Robot [8]

From the picture Figure 2, the prototype in the study has 6 servo joins in implementing the robot manipulator.

2.3. Collector Robot
The collector robot is a designation of a system that can distribute certain objects from one place to another. The robot collector can replace the role of humans in cases of garbage collection in the scope of a building or a broad environment [9]. The following is an example of the design of a robot collection trash like the one in Figure 3.

Figure 3. Collector Robot.[9]

In this study the robot recognized the surrounding environment using ultrasonic sensors. The ultrasonic sensor is used to recognize the surrounding environmental patterns to make certain decisions.

2.4. Fuzzy Kohonen Network (FKN)
Artificial neural networks (ANN) and fuzzy logic are two different methods used to present human intelligence in working on data processing, although in the implementation the approach has different perspectives. As a stand-alone system, the two methods have unique features and have their own limitations which are contradictory.

ANN has learning abilities, but cannot explain the reasoning process that is done. While fuzzy logic does not have learning capabilities, it can explain the reasoning process that is carried out based on rules in the knowledge base. Therefore, each method only has the ability to solve one aspect of the problem, but cannot provide a total solution.

Until now, a lot of interesting research has been done to integrate between ANN and fuzzy logic. The results of the integration of the two resulted in a new artificial intelligence method called Neuro-Fuzzy. The Neuro-Fuzzy method is basically fuzzy logic that uses learning algorithms derived from ANN to determine the basic parameters in the sample data. The Neuro-Fuzzy method generally provides a better solution than each individual component.

FKN is one type of method from Neuro-Fuzzy which is the result of integration between fuzzy logic and Kohonen ANN [10]. Kohonen has the advantage of learning in pattern recognition while fuzzy logic plays a role in managing input and output processes from the introduction of the Kohonen pattern while translating it into the reasoning process based on predetermined rules.

FKN is the result of the development of the development of the FKCN (Fuzzy Kohonen Clustering Network) method. One of the weaknesses in the FKCN method is the long training time to look for weights that meet performance [11]. So to overcome this the learning process which was originally unsupervised was simplified to be supervised, known as the FKN method [12]. It is said to be supervised because the weights used are unchanged and replaced with fixed weights determined based on expert knowledge in terms of using rules on fuzzy logic, so the training process can be eliminated. This is the basis of the FKN technique.

In the FKN technique, weighting is obtained from changes in the prototype pattern to the input pattern [13]. The pattern comes from experiments using several sample data and ultimately the appropriate weight will be obtained. After determining the weights, there will be a number of prototype patterns that present several variations in the classification of patterns.

After the weight of the FKN is known, the weight can be recalled directly when the actual data has been entered, this is what is called the learning process in the FKN method. Without the training process and only doing the learning process this is the difference between the FKN method and the FKCN method.

3. Method

3.1. Hardware design of GACOBOT

At this stage, the mobile robot is made or assembled to be paired with Ultrasonic sensors. The mobile robot is also equipped with a 2 axis based manipulator system with a tip manipulator connected with grip. Mobile robots move using DC motors and servo motors. In this study mobile robots are designed to resemble four-wheeled vehicles with a similar system and mechanism, four-wheel drive with 2 rear wheels as an impeller and 2 front wheels as a control centre and a manipulator system designed to lift garbage boxes and distribute them. Figure 4 shows the design of the Car-Like Robot. The hardware schematic in the Car-Like Robot design is shown in Figure 5.

Figure 4. Collector Robot.

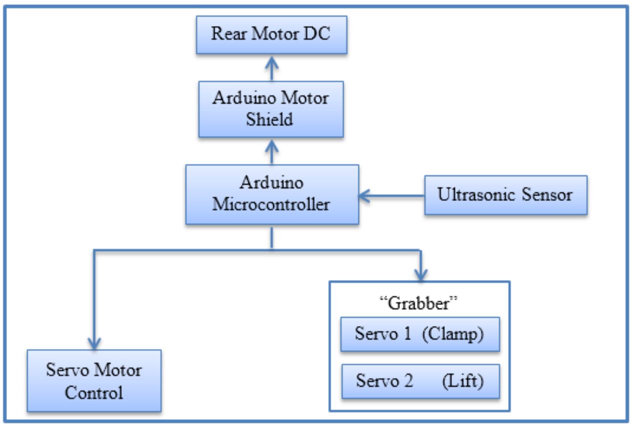

Figure 5. Flowchart of Hardware Design Scheme.

3.2. Design of Sensor Placement

At this stage, the ultrasonic sensor placement is designed as input to be processed by the microcontroller to be a distance value. The sensor used is HC-SRF04 as many as 3, 1 sensor is located on the right at an angle of 45˚, 1 sensor is located in the middle at an angle of 90˚, and 1 sensor is located on the left at an angle of 135˚. The right sensor functions to read the obstacles on the right side, the left sensor functions to read the obstacles on the left area, and the middle sensor functions to read the front area which is an object in the form of garbage. The following is the sensor display that can be seen in Figure 6.

Figure 6. Design of Ultrasonic Sensor.

3.3. Design of Grabber

At this stage, a grabber is designed as an arm robot to lift objects detected by robots as garbage. At the grabber there are 2 servo, the first servo serves to clamp the object, the second servo serves to lift the grabber. Servo for clamping using SG90 servo, where the servo can rotate 180˚, where the torque weight is 1.9 kg and requires power of 5V. While to lift the grabber using MG996R servo, where the servo can rotate 180˚, where the torque weight is 10 kg and requires power of 5V. The grabber will be placed on the front of the robot's Garbage collector.

In the design of the SG90 servo, to clamp the object using an angle of 180 degrees, while to open the clamp using a 90˚ angle. In designing MG996R servo, to lift objects using a 90˚ angle, while to lower objects using 0 degree angle. The following is the angle on the SG90 servo in Figure 7 (A) and (C), while MG996R is in Figure 7 (B) and (D).

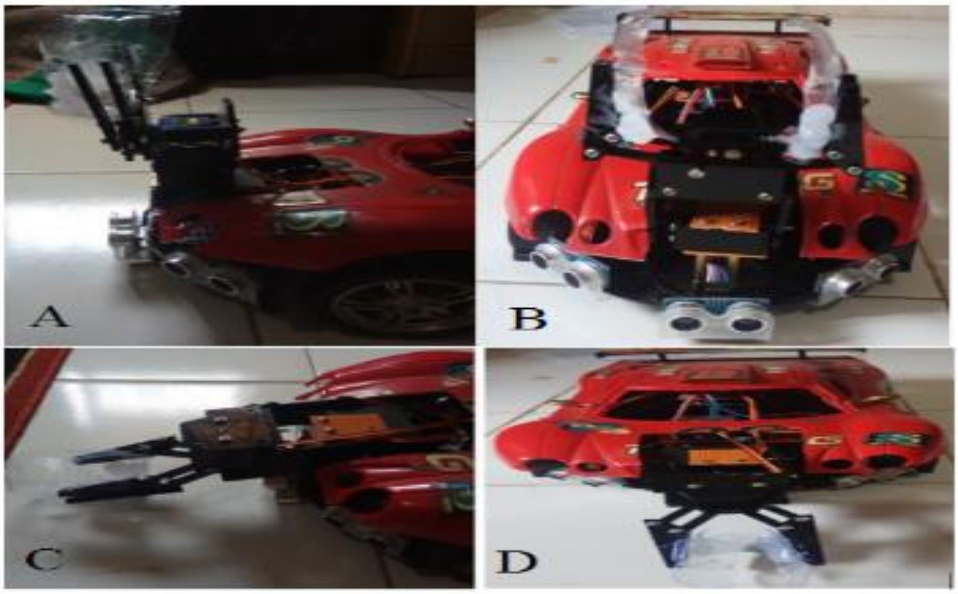

Figure 7. (A). Angle of 90˚ SG90, (B). Angle 90˚ MG996R, (C). Angle 0˚ MG996R, (D). Angle of 180˚ SG90

3.4. Design of Servo Control

At this stage, the design of the servo control is carried out as a directional control of the Garbage collector robot. Servo control is located on the front of the robot Garbage collector as a directional control centre, 1 servo, where the servo used is MG996R servo. Where in the direction control design, the angle used is 60˚ angle for leftward control, 90˚ for forward control, 120˚ for rightward control. The following are the directional control angles in Figure 8 (A), (B) and (C).

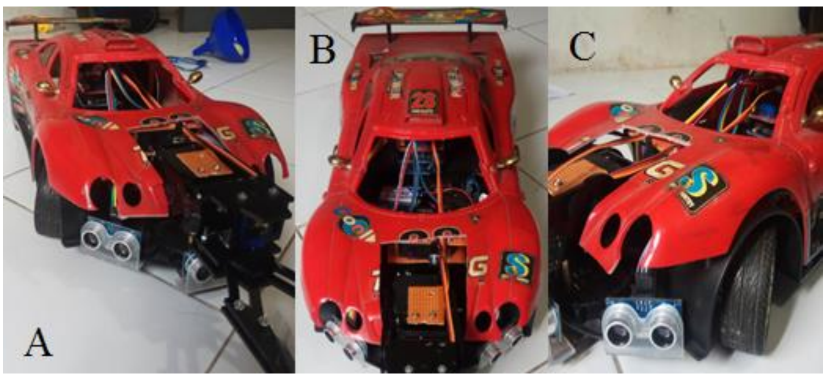

Figure 8. (A) Angle of 60˚, (B) Angle of 90˚, (C) Angle of 120˚

3.5. Software design of GACOBOT

The design of the FKN algorithm consists of several steps, namely (1) quantization of distance sensor values, (2) classification of environmental patterns, (3) membership functions and rule bases, and (4) output of DC motor speed. All of these steps will be explained through flowcharts, algorithms and explanations for easier understanding. The flowchart of the FKN algorithm can be seen in Figure 9.

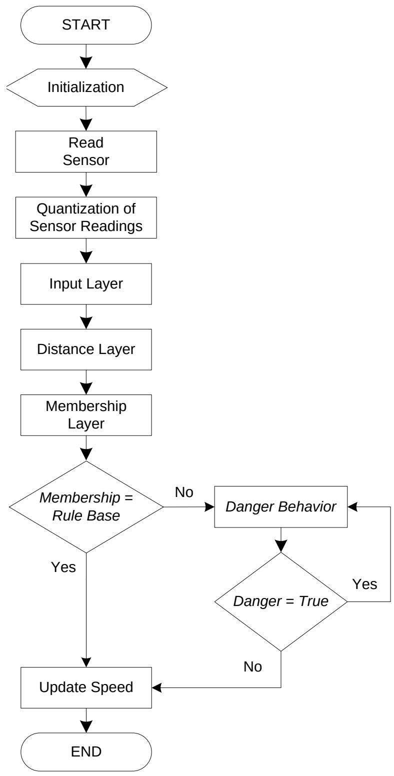

Figure 9. FKN Algorithm Flowchart.

Based on Figure 9, it is known that before further processing in the FKN algorithm the value of sensor readings will be quantized first into the weight value. The weight value of each sensor will be an environmental pattern that will be compared with the pattern that has been implanted in the robot agent and will be processed through 3 FKN layers. If the pattern is recognized, the robot agent will move according to the reference speed implanted. However, if the pattern is not recognized, it will be considered to be in the danger area.

3.6. Design of Environmental Classification Algorithms

This robot agent navigation algorithm uses the FKN method for pattern recognition. Before entering the FKN method, readings from the proximity sensor (Ultrasonic SRF04) which are worth centimeters (cm) are quantized first into the weight values so that they can later be compared with the weights in the implanted pattern. The quantization formula for sensors uses Eq. (1).

$$x_i = \begin{cases} 1 & ;0 < d_i \le 10\text{cm} \\ 2 & ;10 < d_i \le 19\text{cm} \\ 3 & ;19 < d_i \le 28\text{cm} \\ 4 & ;d_i > 28\text{cm} \end{cases} \tag{1}$$

where i is the sequence of sensors.

Based on the predetermined value distribution, the distance quantization algorithm can be seen in Figure 10.

```
Declaration
integer    :  array x[3], i ;       real : array s[3];
Description
For i = 1 to 3 do
        Read    (s[i])
        If  ( s[i] ≤ 10 ) then
                x[i]  ←  1
        Else If  ( s[i] > 10   and    s[i] ≤  19 )
then
                x[i]  ←  2
        Else If  ( s[i] > 19   and    s[i]  ≤ 28 )
then
                x[i]  ←  3
        Else
                x[i]  ←  4
        End If
End for
```

Figure 10. Distance Quantization Algorithm.

3.7. Design of Environmental Classification Algorithms

Environmental classification is needed by robots as a form of pattern recognition. 7 types of obstacle configuration classification used in this study are shown in Fig. 11. The results of combining the fuzzification process and the combination of 7 classification patterns in this FKN cause us not to consider other obstacle configurations which are the main uses of the membership layer. This results in very few control rules (control rules) compared to conventional Fuzzy control methods [12].

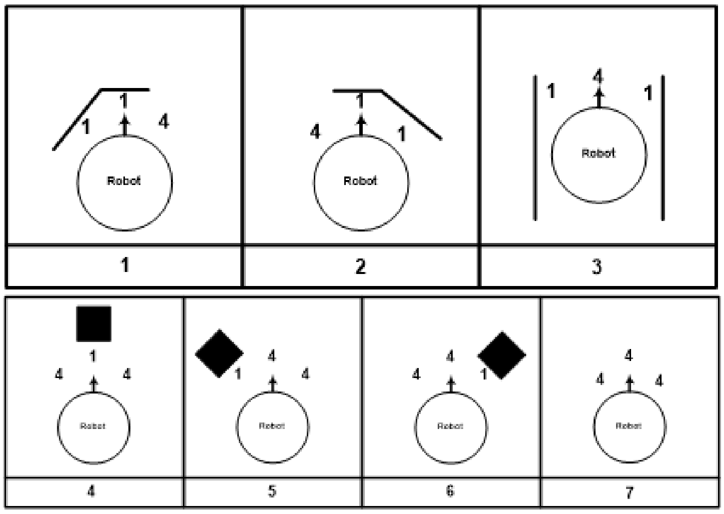

Figure 11. FKN Environmental Classification.

4. Result And Discussion

In this section, some experiments and data from sensors and robots are described. The purpose of this test is to determine the performance of the system that has been designed, and analyse the data obtained.

4.1. *Ultrasonic Sensor Trial*

In this test to find out whether the ultrasonic sensor is functioning properly. The following is a test of the distance on the ultrasonic sensor in Fig. 12 (A), (B) and (C).

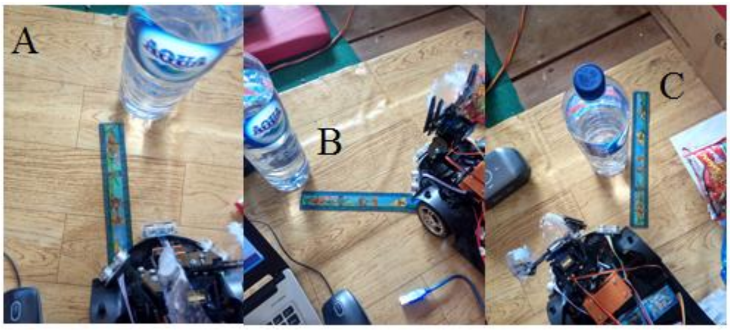

Figure 12. (A) Trial of the center sensor, (B) Left distance trial, (C) Right distance trial

The results of the distance sensor trial in detail can be seen in Table 1.

Table 1 Ultrasonic Sensor Test Results

Actual Distance (cm)			Test Result (cm)			Test Error (%)		
Right	Center	Left	Right	Center	Left	Right	Center	Left
10	10	10	10	10	10	0	0	0
15	15	15	15	15	15	0	0	0
18	18	18	18	18	18	0	0	0
20	20	20	20	20	20	0	0	0

Based on the test in Table 1 shows the same results on the right, center and left sensors. From the 4 tests, the ultrasonic sensor shows the same result as the actual distance, with an error value of 0%.

4.2. *Control Servo Trial*

At this stage, servo control trial is carried out where in the angular direction will be tested, by providing obstruction at each servo angle of control whether the servo moves according to the obstacle detected by the sensor.

4.2.1. *Angle 90˚ Trial*

To prove the movement of the 90˚ angle servo control straight, the test is done by placing the obstacle in the middle area, the moving servo moves to detect the distance to the obstacle. Trial the straight 90˚ angle servo control movement can be seen in Figure 13.

Figure 13. Servo Control Movement 90˚ Straight.

4.2.2. Angle 60˚ Trial

To prove the movement of the 60˚ angle servo control straight, the test is done by placing the obstacle in the left area, the moving servo detects the distance to the obstacle. Trial the 60˚ servo control angle motion to the right can be seen in the following Figure 14.

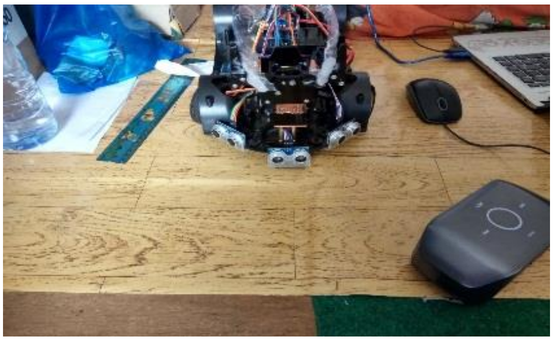

Figure 14. Servo Control Movement 60˚ Right.

4.2.3. Angle 120˚ Trial

To prove the movement of 120˚ left servo control, the test is done by placing the obstacle in the right area, the moving servo detects the distance to the obstacle. Trial the movement of 120˚ servo control angle to the left can be seen in Figure 15.

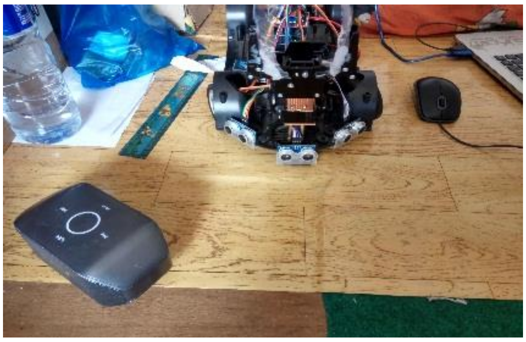

Figure 15. 120˚ Left Servo Control Movement.

4.3. Garbage Collector Robot (GACOBOT) Experimentation

4.3.1. Experiment on Egg Waste

At this stage, a whole experiment or experiment on the garbage collector robot (GACOBOT) is done. This experiment will be carried out in an open environment, where there will be an obstacle for the garbage collector to move the robot to avoid the obstacle to retrieve the garbage in the free environment. In the first experiment, a plastic egg will be taken as the object to be taken. The results of the distance to the obstacle that was successfully detected by robot sensors can be seen in Table 2.

Table 2 Experiment of Egg Waste

Process	Sensor Detection (cm)			Angle Control (°)
	Right	Center	Left	
1	59	262	244	60
2	64	73	119	90
3	59	253	33	90
4	58	61	106	60

Table 2 Experiment of Egg Waste (continued)

Process	Sensor Detection (cm)			Angle Control (°)
	Right	Center	Left	
5	112	238	26	120
6	29	52	97	60
7	211	39	25	120
8	49	163	25	90
9	222	46	137	90
10	97	213	181	90
11	94	206	111	90
12	27	71	112	60
13	27	82	106	60
14	156	97	70	90
15	135	171	103	90
16	134	61	117	90
17	152	15	230	90
18	123	162	294	90
19	118	7	10	90

When the sensor is detecting an object less than 14 cm, the garbage collector robot will stop and transport the egg. The results of the grabber angle when transporting the eggs can be seen in Table 3.

Table 3 Egg Grabber table

Process	Clamp Servo (°)	Lift Servo (°)
1	90	-
2	90	0
3	180	0
4	180	120
5	90	120

From Tables 2 and 3 we can know that garbage collector robots move in an environment free to look for egg waste, successfully transporting the egg waste.

4.3.2. Bottle Cap Experiment

In the second experiment, a bottle cap will be taken as the object to be taken. The results of the distance to the obstacle that was successfully detected by robot sensors can be seen in Table 4.

Table 4 Experiment of Bottle Cap Waste

Process	Sensor Detection (cm)			Angle Control (°)
	Right	Center	Left	
1	51	75	50	90
2	66	68	41	90
3	54	63	35	90
4	49	64	33	90
5	48	61	27	120
6	76	43	20	120

Table 4 Experiment of Bottle Cap Waste (continued)

Process	Sensor Detection (cm)			Angle Control (°)
	Right	Center	Left	
7	104	190	98	90
8	82	41	136	90
9	34	205	347	90
10	30	36	191	60
11	81	190	83	90
12	126	183	144	60
13	157	63	98	60
14	135	180	230	90
15	150	79	122	90
16	119	157	17	120
17	49	119	12	120
18	62	17	88	90
19	140	8	45	90

When the sensor is detecting an object less than 14 cm, the garbage collector will stop and transport the bottle cap. The results of the grabber angle when transporting the bottle cap can be seen in Table 5.

Table 5 Bottle Cap Grabber table

Process	Clamp Servo (°)	Lift Servo (°)
1	90	-
2	90	0
3	180	0
4	180	120
5	90	120

From this second experiment, the garbage collector robot successfully transports plastic bottle waste, with the same obstacle. From these two experiments it was known that the garbage collector robot managed to transport garbage with 2 different objects.

5. Conclusion

The conclusion of this research is that the implementation of the GACOBOT application to retrieve garbage has been running well for experiment on egg samples and bottle caps. Tables 2 and 4 prove that when the ultrasonic sensor in the middle detects an object with a distance of less than 14 cm, the robot will stop and perform the object retrieval procedure. Whereas in Tables 3 and 5 prove the object taking process by setting the angle of the clamp and lift on the grabber. This is supported by the comparison of the error rate measurement of small-distance object distances between the measurement results of the sensor and the measuring instrument (ruler). So that the servo motor and the DC motor control system made can be integrated in accordance with the state of the garbage in front.

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