Development of Low-Cost Auto Robot Collecting Floating Garbage using Shortest One-Way Path of Energy Saving

Sumitra Nuanmeesri, Lap Poomhiran

Abstract: *Today, floating garbage is a global problem that needs to be cleared and disposed of from the sea and rivers or canals. Especially the floating plastic garbage that directly affects the ecology and the aquatic animals. This paper proposes to develop a low-cost auto robot from waste materials in the household, school, or agriculture, then combines with the Internet of Things technology and focusing on the power energy saving with the highest accuracy in operation of floating garbage collection. The mixed-mode is a new method to define the shortest one-way path for the auto robot to detect and collect the floating garbage on the water surface. It can eliminate the blind spot area that occurs when using the stationary mode and cover mode. As a result, the accuracy of the auto robot system in mixed-mode is 98.3%. It found that the development of the shortest one-way path for auto robot collecting the floating garbage by mixed-mode provides the highest efficiency in detecting floating garbage and also helps to save overall costs.*

Keywords: *auto robot, energy saving, floating garbage, internet of things, image processing, low-cost, shortest one-way path.*

I. INTRODUCTION

Today, most products containing plastic components. Becoming more waste and an international issue, particularly in different water sources, plastics are not recycled but are left in various ecosystems. For example, in the ocean study, over 150 million tons of waste from plastics found to be deposited onto the sea by consumers totaling eight million tons per year [1]. Moreover, Some marine animals eat these plastics. After all, they think they are food because they shaped like some marine animals. Every year, there are many aquatic animals die, such as sea turtles, whales, seals, and seabirds, because of plastic waste pollution [2].

Therefore, collaborating to get rid of plastic waste floating in the water is considered to help aquatic animals, aquatic ecosystems, and to help reduce pollution problems.

Nowadays, many new technologies can be applied to benefit the ecosystem, especially the Internet of Things (IoT) technology. The technology has been designed and manufactured to be versatile and can be quickly developed at a low-cost. Therefore, the application of modern technology, together with environmental conservation, is a way to help the world to exist under an ecosystem that requires support. Even if integrated with social media such as LINE, it will make it more powerful and helps to attract more users and usefulness. In Thailand, there are over 44 million LINE users, which are accounts for 78 percent of mobile internet users [3]. The objective of this research is to develop an automatic robot that can collect plastic floating garbages by considering the methods of saving energy, time, and cost but with the highest management efficiency.

II. RELATED WORKS

For the development of automated robots for floating waste collection, intending to calculate the shortest path to save energy and time, the researcher has studied related research as follows. Abrams [4] shown that the robot can collect waste and tracking aquatic animals in the water, but it requires humans to control it. Moreover, the automatic robot system helps to clean up plastic wastes at fifty thousand kilograms per day in India, and alert to the worker when the bin is full [5].

Some studies found the method to control the robot movement and pathway. For example, the genetic algorithm is used to building up robot pathfinding [6], and the zigzag path was applied for robot movement to cover all areas [7]. Besides, some sensors such as ultrasonic, passive infrared, and camera used to process object detection [8].

An automated robot developed by [9] can detect floating garbages, but there are blind spots in the corner or at the edge of the pool. Therefore, this research aims to develop a low-cost auto robot collecting the floating garbage by focusing on the shortest one-way path to save power consumption and other costs.

III. RESEARCH METHODOLOGY

In the development of an automated robot for floating plastic garbage collection, with the emphasis on designing robots to set waste collection routes that save energy, but the roll covers the working area. There are many steps for development as follows.

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A. The robot structure design

The most crucial thing in robot design in this work is the use of waste materials that are left in the household or from various activities that are materials that are lightweight and can float on water as the main components of the robot structural, which has the following components.

- *Robot base:* Four 5-liters bottles of drinking water used to build the robot base. It is buoyant to support structures and other components floating above the water surface. Two water bottles on each side are assembled to support other components that will be installed on top.
- *Robot controller zone:* This component used to install all IoT controller devices such as microcontroller board, battery pack, camera, and sensors. The central robot controller zone made from cartons or cardboards for packing household appliances such as television, refrigerators, and washing machines. Containers or cardboard was re-build to a box that customize to the size as designed and wrapped with tape to prevent wet or moisture.
- *Garbage bin:* The garbage bin consists of plastic grates found in gardens or agriculture. It shaped into a square box with a single front side that is open for garbage floating along the water. This component is airy, making it easy to see and lightweight, waterproof as well.
- *Paddle:* It made from the future board that found in the school or advertising board. It used to drive the robot movement in any direction.
- *Garbage picker:* It made up of a future board that serves to push or grab the floating garbage on surface water into the trash.

All waste material components used to assemble the robot structure are shown in Figure 1.

Fig. 1. The waste material components of a low-cost robot.

The robot structure designed as a top view, front view, and side view, it can be illustrated in Figure 2.

(a) Top view

(b) Front view   (c) Side view
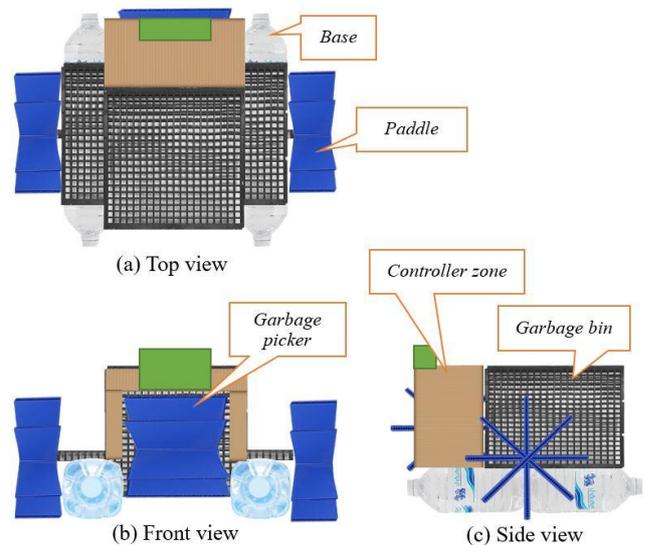
Fig. 2. The robot structure design for collecting floating garbage.

B. IoT design

According to Figure 2(c), the robot controller zone consists of electronic devices by using IoT. Only robot paddle, two motors to drive a robot are excluding from the controller zone. All IoT devices list as following.

- *ESP32 DevKitC:* It is the development kit board, which is the main controller unit for the auto robot. It has 38 pins for input and output, both digital and analog signals. Wi-Fi module included on this board.
- *Two brushed DC geared motors:* Both of these motors used to support the robot to move in all directions. It is a motor with low-speed but high torque that it can be easier to bring the robot together with the collected waste.
- *Motor drive module (L298N):* This module controls the operation of both motors above to control the direction of the movement of the robot.
- *Single brushed DC geared motor:* It is a motor with a slight speed for acting in the garbage picker to grab or push the garbage floating in the front of the robot into the garbage bin.
- *12V-Single channel relay:* It controls the motor that is a garbage picker to operate when floating waste is detected.
- *Ultrasonic sensor module (HC-SR04):* It is a sensor that uses sound waves to measure the distance between objects far away with a working range between 0.03 to 3 meters. It serves to detect objects that float on the water surface and the edge of the pool.
- *Camera module (OV2640):* This module is for photographing objects that robots have detected with an ultrasonic sensor for sending images to process objects or sending messages to users as well.
- *Micro servo (SG90):* It is responsible for controlling the vertical angle view of the camera.

It can track the objects that are floating until garbage has collected.

▪ *Battery pack:* It is the power source for the processor within the controller zone and all activities used in the robot's operations. This battery pack consists of 24 cells of rechargeable battery in series 18650 with a current of 3.4 Amperes (A) and a voltage of 3.7 Volts (V) capacities for each cell. By connecting each cell in series and parallel, resulting in the final electric current of 27.2A and 11.1V that can support 12V IoT devices.

The power consumption of IoT devices used to construct the robot shown in Table I, and the IoT design can illustrate in Figure 3.

Table- I: The power consumption of IoT devices and sensors for the auto robot collecting floating garbage

IoT devices and sensors	Voltage	Power consumption (mA)
ESP32 DevKitC (no WiFi operation) at 240 MHz	3.6V	50
ESP32 DevKitC (WiFi operation) at 240 MHz	3.6V	130 to 230
Two brushed DC geared motors	12V	0.5833 (7 Watts)
Motor drive module (L298N)	12V	36
Single brushed DC geared motor	12V	0.0325 (0.39 Watts)
12V-Single channel relay	12V	0.0375 (0.45 Watts)
Ultrasonic sensor module (HC-SR04)	5V	15
Camera module (OV2640)	3.3V	0.0424 (0.14 Watts)
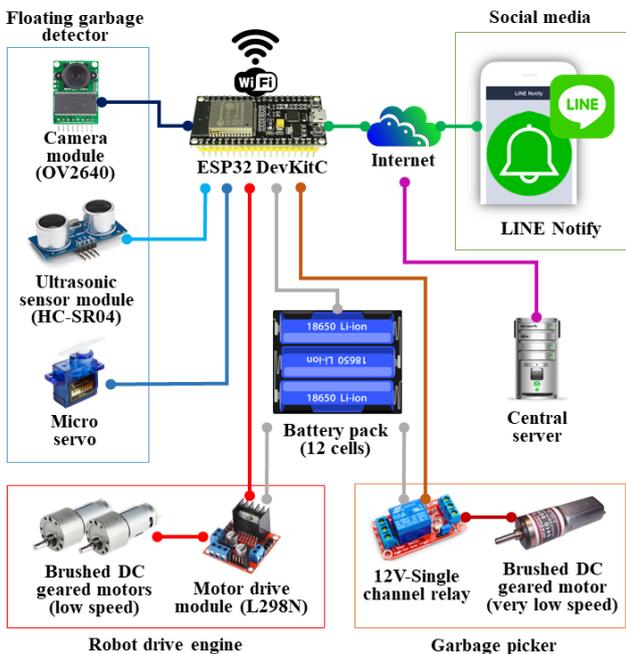
Fig. 3. IoT devices and sensors used to construct the robot.

C. Shortest one-way path of energy saving

According to Nuanmeesri [9], there are two modes of the robot operation: stationary mode, and cover mode. Both modes can be illustrated in Figure 4.

(a) Stationary mode   (b) Cover mode
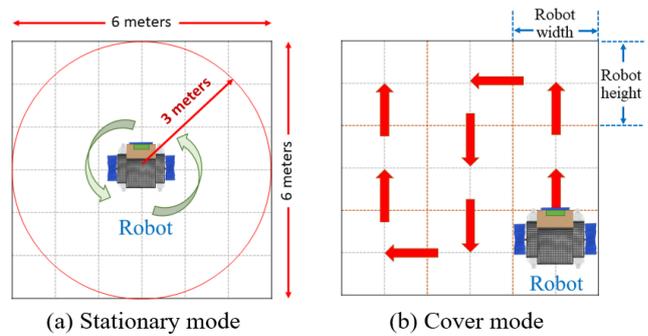
Fig. 4. The original of the robot operates in stationary mode and cover mode.

This research designed a robot walking path by combining both modes. This method was called mixed-mode. According to the ultrasonic sensor datasheet, it can operate to detect an object in the distance range of 2 to 400 centimeters. The researchers control the effectual distance range does not exceed 300 centimeters that ultrasonic sensors can detect an object.

Considering Figure 4(a), the stationary mode, it can cover the area in 36 square meters, which is the robot standing by and waiting for the floating garbage move following by the water flow. This work, the robot dimension, is 100x100 centimeters. The researchers adjusted the area for the robot to detect floating debris by specifying the area with a robot half-size combined with the distance that ultrasonic can detect. Resulting in a new coverage area equal to 49 square meters calculated in (1) and (2).

$$D_{new} = \left(\frac{W_{robot}}{2} + D_{sensor} \right)^2 \qquad (1)$$

$$A_{new} = D_{new}^2 \qquad (2)$$

Where:

D_{new} is the new distance the reach to detect an object floating in the water.

A_{new} is the new coverage area of the robot.

W_{robot} is the width of the robot dimension (100 centimeters).

D_{sensor} is the ultrasonic sensor distance detection (300 centimeters).

Considering the mixed mode, the shortest one-way path applied to cover all new coverage areas. The robot works by moves forward to each new coverage area, then rotate left by itself in a total of 12 times to cover the area in 360 degrees within 49 square meters. Each rotation that cover area in 30 degrees. However, there are a few areas that do not detect by a sensor, it was called the blind spot area. These blind spot areas are shown in Figure 5. The blind spot areas eliminated by move forward the robot in a half-distance of coverage area then rotates twice times on the right-hand side of the robot to detect the floating garbage at the blind spot area right-hand side. After that, turn the robot around 180 degrees to detect an object on the left-hand side by rotating twice times. When finished, it will move forward to enter the new coverage area that is next. The robot operation for blind spot areas elimination shown in Figure 6.

Fig. 5. The blind spot areas when the robot rotates 360 degrees.

Fig. 6. The blind spot areas eliminated strategy in mixed-mode.

When comparing the cover mode and the mixed-mode in our design, it can calculate the power consumption and total distance for moving the robot to cover all target areas. For cover mode, the total distance can calculate in (3).

$$D_{total} = \frac{A_{total}}{D_{robot}} \qquad (3)$$

Where:

D_{total} is the total distance that robot movement all cover areas.

A_{total} is the total area in the pool that reserved for robot operation.

D_{robot} is the dimension of a robot, the robot width multiply by robot height (from top view).

For mixed-mode, according to a new distance in (1), the total distance can calculate in (4).

$$D_{total} = \frac{A_{total}}{D_{new}} \qquad (4)$$

For example, the total area of the pool is 1,000 square meters, and the dimension of the robot is 1x1 meters. For cover mode, the total distance calculates in (3), it is 1,000 square meters divided by a square meter. The 1,000 times of robot movement in cover mode. In contrast, the total distance in mixed-mode that calculate in (1) and (4), it is 1,000 square meters divided by 49 square meters. The result is 20.41, meaning that the robot moves 21 times to cover all areas in a pool. This mixed-mode reduces 97.9% of the distance to move the robot.
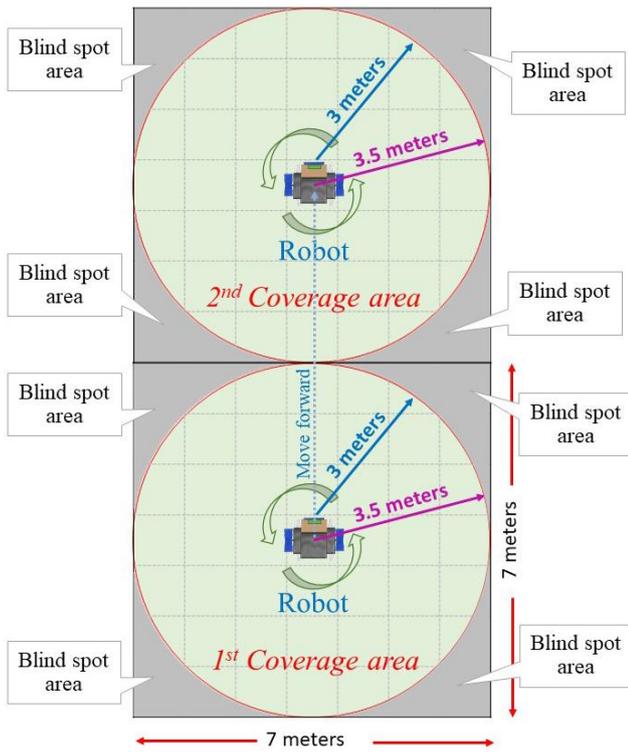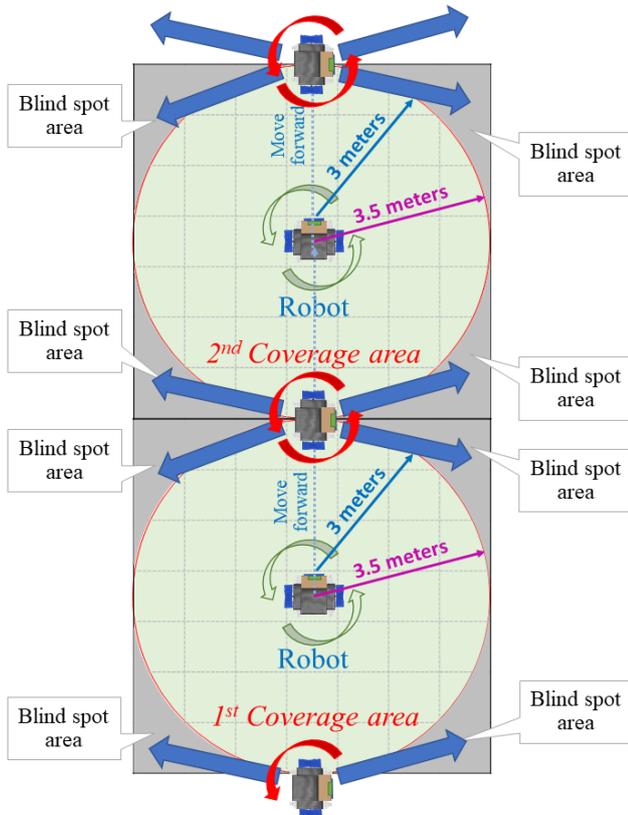
D. System development

Arduino IDE version 1.8.10 used to develop the system for control the robot for movement, garbage detection, grabbing, and internet communication. This system developed and loaded into the ESP32 DevKitC board. During floating garbage detection, the ultrasonic sensor will be detecting an object on the water surface. If an object found, it will activate the camera for snapshot image then send it to the central server. At the central server, the web application developed and installed based on Python version 3.6.5. Three thousand images used in the training process for floating garbage classification. This server will process the image to classify the object, which is garbage or not, by using the Fast Approximation Nearest Neighbor algorithm with low power consumption [10]. If an object is a plastic floating garbage such as a bottle, the garbage picker will activate to grab and push the garbage into the bin. Finally, The ESP32 will send the message to LINE Notify, which is a free mobile application on social media to the user who is system manager.

E. System evaluation

This system evaluated in terms of system efficiency and energy saving by comparing it in three modes: stationary mode, cover mode, and mixed-mode. All evaluations tested in three kinds of pool and canal, which is a low speed of water flow. The first kind is the small canal that is not too wide (6.5x50 meters for width and length, respectively). The second kind is a pool that formed in a rectangle area with 16x30 meters dimensional. The last kind is the none rectangle area in 560 square meters.

The floating objects were set randomly, both garbage and none garbage, which are the same amount of floating objects. This system tested in a closed system. At the end of the evaluation, we check the remaining power source of a battery pack installed on the robot.

IV. RESULT AND DISCUSSION

In this experiment, the robot was installed, tested, and evaluated in a closed system with a maximum of robot operation time limit at 180 minutes. The researchers define A1, A2, and A3 are the small canal, rectangle area, and none rectangle area, respectively. Moreover, the robot operation modes defined as S, C, and M for stationary mode, cover mode, and mixed-mode, respectively. The results of the system evaluation shown in Table II.

Table- II: The result of system evaluation of robot collecting floating garbage in three mode

Term of evaluation	Results of system evaluation								
	A1 (6.5x50)			A2 (16x30)			A3		
	S	C	M	S	C	M	S	C	M
Total area (square meters)	325	325	325	480	480	480	560	560	560
Operation time (minutes)	89	77	44	180	95	53	180	117	68
Power consumption (%)	35.2	51.4	22.9	43.1	69.5	38.0	40.4	85.9	45.7
Robot walking distance in real-world (meters)	165	352	137	53	495	269	26	614	314
Floating garbage remaining (%)	12	4	0	92	6	1	96	8	2

According to Table II, the mixed-mode consume all resources less than other modes. For mixed-mode, in the term of the operation time, it takes 44, 53, and 68 minutes for the small canal, rectangle area, and none rectangle area, respectively. For the power consumption, it consumes 22.9%, 38.0%, and 45.7% of a battery pack for the small canal, rectangle area, and none rectangle area, respectively. For the robot walking distance in the real-world, it moves on the water surface at 137, 269, and 314 meters for the small canal, rectangle area, and none rectangle area, respectively. Last, the floating garbage remaining, mixed-mode remains a few floating garbage in the testing area. When compares between the cover mode and mixed-mode, the resource consumption of mixed-mode is nearly half of cover mode consumption.

For the system efficiency evaluation, the results show in Table III.

Table- III: The efficiency of robot collecting floating garbage in three mode

Indicators	Accuracy (%)		
	Stationary mode	Cover mode	Mixed mode
Floating object detection	89.5	98.2	99.1
Floating garbage classification	92.5	92.5	92.5
Floating garbage collecting	100.0	100.0	100.0
Movement cover area defined	90.0	99.2	100.0
Messaging to social media	100.0	100.0	100.0
Average mean	**94.4**	**98.0**	**98.3**

According to Table III, the mixed-mode has the accuracy higher than stationary and cover mode in terms of floating object detection and movement cover area defined. For the movement cover area defined, the robot can cover all areas by 100%. Overall, the average mean, the accuracy of mixed-mode at 98.3%, is higher than other modes.

Considering the results of the stationary mode, when the area is more wide or increased, it will reduce the efficiency of the floating object detection. Because this mode will not move continuously like other modes Which will move in the radius that is at the beginning, which is suitable for the case of water flowing through the robot that is responsible for monitoring or detecting objects that float into the specified radius only.

V. CONCLUSION

The low-cost auto robot collecting the floating garbage, it constructed by waste materials found in household, school, or agriculture. When it combines with the IoT technology, it is useful to help the ecology. This work, the auto robot system, was developed in Arduino and Python for improving the plastic floating garbage detection and collection. The mixed-mode is a new method for the shortest one-way path to save the cost of time and power consumption. In the same way, when tested and compared with other modes, it was found that this mode was more efficient in collecting floating garbage than other modes. As a result, the accuracy of the auto robot system in mixed-mode is 98.3%. It can be said that the development of the shortest one-way path for auto robot collecting the floating garbage by mixed-mode provides the highest efficiency in detecting floating debris and also helps to save overall costs.

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