Development of Low-Cost Auto Robot for Plastic Floating Garbage Collection using IoT

Sumitra Nuanmeesri

Abstract*: *Nowadays, there is still much plastic waste floating in the sea and rivers, causing a limited number of officials to take care of this waste is not thoroughly. In this paper propose to develop the low-cost auto robot from waste materials based on Internet of Things for grabbing and collecting the floating garbage in the closed of water pool. The sensors and motors were mixed to control the robot on water surface and collect the plastic floating waste which is detected by sensors. To classified the floating garbage, the Fast Approximation Nearest Neighbor algorithm was applied to system in the web platform. The activities for garbage collection were submitted to social media such as LINE notify application. As a result, the auto robot system has the accuracy value at 94.4% and 98.8% for stationary mode and cover mode respectively.

Keywords*: *auto robot, floating garbage, Internet of Things, image processing, social media.

I. INTRODUCTION

Nowadays, many products that contain components from plastic. Due to the need to use a lot of plastic, when these plastics are no longer needed for use, they will become more waste and become an international problem especially in various water sources. From the survey at the ocean, found that there are more than 150 million tons of plastic waste, which is expected to cause an average of 8 million tons per year to be dumped into the sea by users [1]. And damage aquatic animals that think of these plastic wastes as food. According to Surfer against sewage (SAS) [2] shown that the pollution from these plastic wastes directly affects and kills sea turtles, whales, seals, and seabirds in every year.

The source of garbage is not just caused by dumping it into the sea or the water sources. Most garbage is caused by deliberately and unintentionally dumping into the river. For example, the garbage is not dumped into the tank and sprayed into the water. That garbage will flow into the sea along with the tide system in another way. Thailand is an agricultural country with many rivers and canals scattered throughout villages. Solving problems and managing waste should start at the source or houses near the river to have the technology to help check and collect waste at an economical cost by using waste materials together with the invention of sensor technology and the Internet of Things (IoT) including social media such as LINE. From statistics found that Thailand has the most LINE users. According to current data, there are more than 44 million users or about 78% of the total mobile internet users in Thailand [3]. It should help to make the disposal of floating waste easier to reduce waste in rivers and the sea is another way in conjunction with the conservation of the environment saving.

Revised Manuscript Received on December 30, 2019.
* Correspondence Author
Sumitra Nuanmeesri, Assistant professor, Department of Information Technology, Suan Sunandha Rajabhat University, Thailand. Email: sumitra.nu@ssru.ac.th

II. RELATED WORKS

It is important to comprehend the existing work done on floating waste collection robots to understand the need for a lightweight, cost-effective and scalable system and propose the solution.

According to Abrams [4], Urban Rivers, a non-profit company based in Chicago that improves water quality in urban areas, has one solution by a robot. Not only for the collection of waste, it can also be used to track wildlife and fish. The robot must be operated by a human.

India Block [5] reported that the 50 thousand kilograms of plastic wastes in the river were cleaned by automatic system per day. It has ability to notify user when the trash is full. The one percent waste from rivers around the world will become 80 percent of the waste in the ocean.

The robot can movement automatically for coverage area. For example, the cleaner robot automatic travels between bottom to top and top to bottom side as the zigzag path [6].

Bharathi et al. [7] develop the smart trash by using IoT monitoring and apply the genetic algorithm to find robot pathway. Several sensors were mixed into the robot such as gas sensor, level sensor, ultrasonic sensor, moisture sensor, and GPS.

Pragna et al. [8] combine the ultrasonic sensor, PIR sensor, and camera for detecting the cars that fast moving via the surveillance system.

In October 2019, LINE shows the user statistics in Thailand. There are 45 million LINE users in Thailand. The average of using is 63 minutes per day [9].

Therefore, this paper aims to develop the low-cost auto robot which has abilities to collect the plastic floating garbage in water sources surface based on IoT and notify message to social media such as LINE.

III. RESEARCH METHODOLOGY

In this paper, the researcher develops an autonomous robot system and integrates it with the LINE application. The main components of the robot consist of components made from waste materials and electronic circuits that drive various mechanisms. The robot system is developed step by step as the following.

A. Robot body design

Robot body that is designed must have a shape that supports four main features: 1) being able to float on water, 2) able to move on the water surface, 3) having hands or arms that can help grab or catch floating debris, and 4) there is a bag or box for the garbage which are detected and grabbed.

Fundamentally, the body of robot's main components are assembled with plastic materials to make the robot lightweight and can float on water. In this work, the researcher collects the waste materials which are plastic and can be found within local communities, such as 5-litres bottle of drinking water, 2.5-gallons paint container, future board, plastic grille, and nylon net in agricultural shown in Figure 1.

Fig. 1. Main body components of a low-cost robot.

The robot was assembled from waste materials according to the design of implementation features shows in Figure 2.

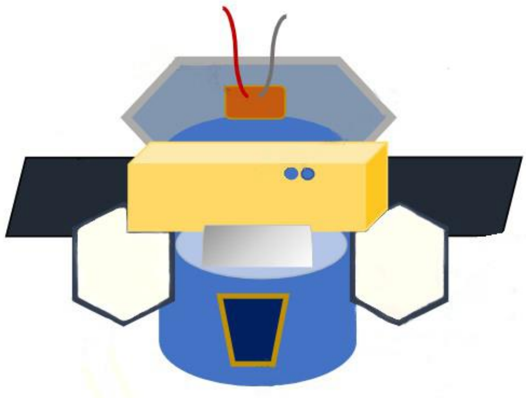

Fig. 2. Main body components of a low-cost robot.

B. Electronic components design and installation

For the design process of electronic components and to support IoT, there is a list of main devices that could be installed as follows.

- *ESP32 DevKitC:* The ESP32 development kit board which has the ESP32-WROOM-32 module with chip series number ESP32-D0WDQ6. It is the main Electronic Control Unit (ECU) for this robot. In this work, the robot needs total 16 digital pins to connect all electronic devices and sensors. This board has 38 pins in total and there are enough digital pins for use in this architecture. One important feature that is required from this board is the ability to connect to the network or internet via Wi-Fi, which will be used for communication with the central server and social media.
- *Motor drive module L298N:* It is dual H-Bridge motor controller and support both power supply with 5 Volts and 12 Volts. This module is connected to two brushed DC geared motors for control robot movement direction as forward, backward, turn left/right, and turn around. It requires 6 digital pins to control the direction and speed of the two DC motor.
- *Two brushed DC geared motors:* It is used to move the robot in any direction with low speed. In this experimental, the robot needs these motors which have speed at 60 round per minute (rpm), maximum output torque at 6,000 grams-centimeter (gcm), and power rating at 7 Watts for supply voltage 12 Volts.
- *Single channel Relay 12Volts:* This relay is used to switch and control a single brushed DC geared motor in one direction for grabbing the floating garbage. A digital pin was reserved for this relay.
- *Single brushed DC geared motor:* It was controlled by a single channel Relay. This motor requires a very low speed for grabbing or collecting the floating garbage on the water surface. The researcher chooses a 12 Volts DC motor which has speed at 14 rpm, 2,000 gcm of maximum torque, and 0.39 Watts of power consumption.
- *Ultrasonic sensor module (HC-SR04):* Ultrasonic sensor is designed for floating garbage detection. It will scan the object by echo a sound and get the sound reflexing back to the receiver. This module can detect an object in a suitable range between 3 centimeters to 300 centimeters. It requires two digital pins for transmission and receiving signals.
- *Camera module (OV2640):* Camera module acts as a sensor for detecting and validating the floating garbage. In the case of detection, the ultrasonic sensor is the first correspondence to detect an object on the water while the camera module is the second stage to identify an object that is garbage or not. Besides, the camera module is used to capturing the image of garbage for the message on social media. The OV2640 camera module was applied in this architecture. It comes with the maximum resolution at two million pixels (1600 x 1200 pixels), 3.6 millimeters of focal length, F2.0 of lens aperture, and lens perspective 78 degree. It requires two digital pins and four specified digital pins (MOSI, MISO, CS, and SCLK).
- *Micro servo:* This servo was used to handle and control the garbage detector devices which including the ultrasonic sensor and camera module. While the floating garbage was detected, the micro servo will be moving for tracking this garbage until it was grabbed into the bin section. Moreover, the servo also helps the devices that detect objects can work more efficiently by being able to adjust the degrees up and down to find garbage with different distances better. A digital pin was reserved for this servo.
- *Power supply/Batteries:* Most power consumptions are three DC motors. The maximum 12-voltage is requiring to support all motors and drive module.

Therefore, the power source should have a large capacity of current to support such use. Usually, the Lithium-ion (Li-ion) battery is a famous in vary of toys' power source and electronic devices. Because it is rechargeable battery. In this case, the researcher decides to use the Li-ion battery in series number 18650. Each battery has the maximum capacity 3.4 Ah and voltage at 3.7 Volts (nominal voltage is 3.6 Volts). To provide 12 Volts of power supply with large capacity, a several batteries were connected in series and parallel form. For example, three batteries with 3.7 Volts were connected in a form of series, the total voltage is calculated in (1).

$$\text{Total voltage (V)} = V_1 + V_2 + V_3 \quad (1)$$

Where $V_1 = V_2 = V_3$, and $V_1 = 3.7$ Volts.

Thus, total voltage is 3.7 + 3.7 + 3.7 Volts (or 11.1 Volts) in one set of series form. In case to increasing the current, each set of series form could be connected in form of parallel. Assumption, if this experimental requires a current at 13.6 Ah in total, each set of series form which has three 3.7 Volts batteries must be connected to four sets of series form. Total current can be calculating in (2).

$$\text{Total current (I)} = I_1 + I_2 + I_3 + I_4 \quad (2)$$

Where $I_1 = I_2 = I_3 = I_4$, and $I_1 = 3.4$ Ah.

Therefore, total current is 3.4 + 3.4 + 3.4 + 3.4 Ah (or 13.6 Ah). Considering in (1), the total voltage is 11.1 Volts. But the robot system architecture requires voltage at 12 Volts for drive the motor system. The DC to DC step up module was applied to tuning the voltage from 11.1 Volts to 12 Volts. The battery system shows in Figure 3.

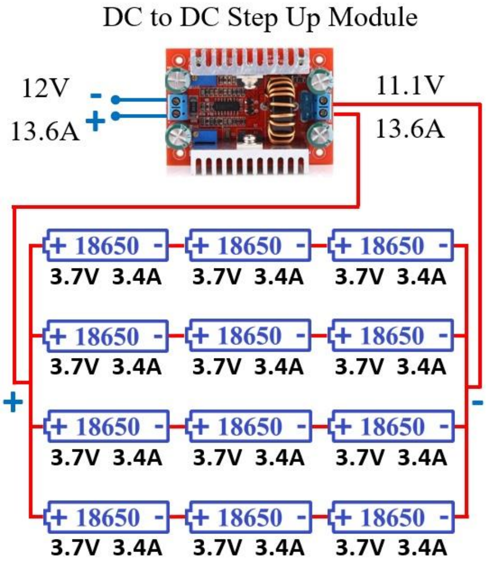

Fig. 3. 18650 batteries formation for 12 Volts 13.6 Ah.

Overall electronics devices were applied to this robot system architecture could be shown in Figure 4.

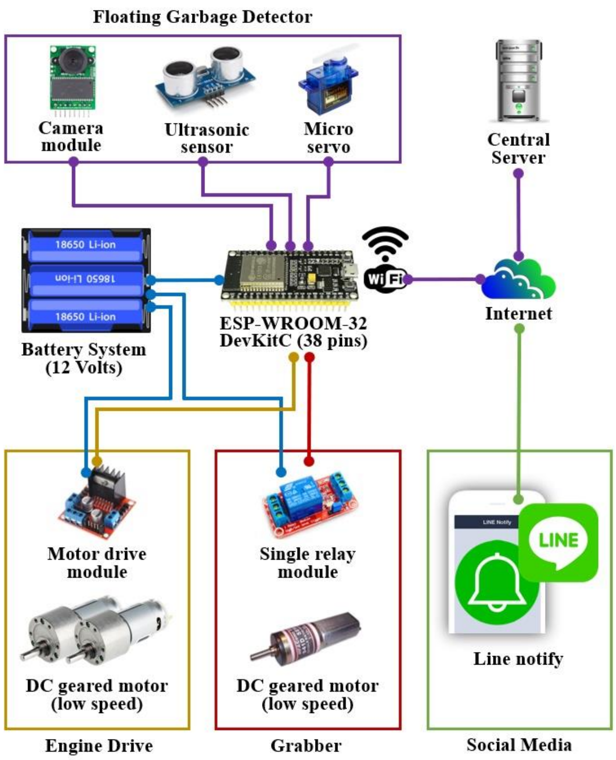

Fig. 4. Electronics and system architecture of robot.

C. Application development

In order to develop the auto robot system, there are two platform of architecture in this system: IoT platform for client side, and web platform for a central server side.

Considering to IoT platform, the researchers have planned and designed the robot to be able to work in two scenarios. First, the stationary mode, the robot will observe the floating object in the water which has a low-rate of water flow, or stagnant water, or in a closed system. In the initial experiment, the floating object will be observed by a robot at a distance of three meters around the robot. It covers an area of 6 x 6 = 36 square meters with 360-degree rotation by itself, shows in Figure 5.

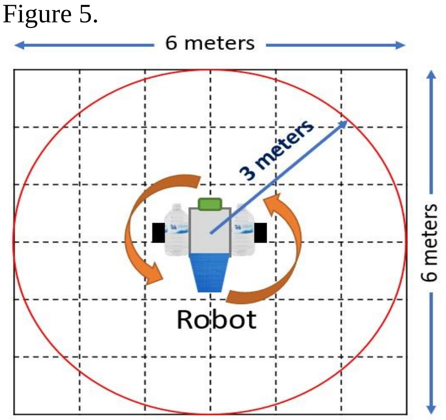

Fig. 5. Robot scenario in stationary mode.

The distance of three meters is variable and depends on the appropriate capability of detecting objects of an ultrasonic sensor and camera module.

Each robot can adjust the distance default value manually. In this mode, if the robot found floating garbage, robot will move to garbage and grabs it, then move backward to the original point of initialization which is stored in a central server database system. While the robot rotated by itself, the degree of rotation will be changing every 30 degrees for every five minutes of rotation time. Because of the ultrasonic sensor is specified the angle view 30 degrees. Also, the robot will take 12 times of rotation per hour for a single loop. This scenario can be changing the parameters for degree of angle view and rotation time in any suitable value.

Second, the cover mode, the robot moving within a closed system. The movement method is in the zigzag pattern by rotating left and right directions alternately throughout until cover all area in a closed system shown in Figure 6.

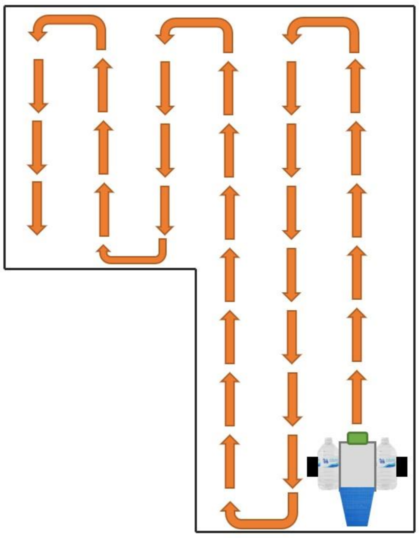

Fig. 6. Robot scenario in cover mode.

For zigzag pattern, robot is moving and stopping for every 3 meters. At point stop, the floating object will be detecting to garbage or non-garbage. If the floating garbage found, the robot will move forward to collecting it and keep moving for every three meters. When the robot moved to the finished point by detected two rims of the water pool, it will be turned around then keep moving forward until detecting two rims of water pool again then rotating in the opposite way for crossing the cover area. For example, if the previous path is the vertical movement, a robot will be converting to horizontal movement.

All algorithm for IoT platform was develop in Arduino IDE version 1.8.10 on Windows 10 x64bit. The robot was automatic controlled by itself as the following steps:

1) The ultrasonic sensor scanning floating object by echo sound signal for every ten seconds. If the floating object is detected, sensor will activate again to confirm an object found, next to step 2.
2) The robot moves closed to floating object by rotating the Floating Garbage Detector heading (see also Figure 4) for tracking this object, then step 3.
3) The camera module captures an image then send it with robot id to a central server by HTTP-Client request for decision making an object. During waiting server corresponding, the robot will be suspending in a second.
4) When central server finished the process for identify object, the robot will send a request with robot id again for get the result of floating object.
5) If an object is a floating garbage, the robot will send the message and image to LINE application with LINE Notify library. Then control the motor as a grabber to flow the floating garbage into a net bin. In the case of non-garbage, robot ignore that floating object, and next.
6) The robot will return to the last position and keep moving or standing by depends on the scenario mode.

The challenge in this work is how to identify an object as the floating garbage. Therefore, the web platform was built on a central server with Python version 3.6.5 programming. The Fast Approximation Nearest Neighbor algorithm was applied in the object classification processing. Because this algorithm requires a low-cost power to process and provides the satisfactory processing results [10]. To training system for classifying floating garbage, the researcher uses three thousand images which are on internet and take a photo by the researcher. There are several kinds of floating garbage which made from plastic. The sample images for training and test data shown in Figure 7.

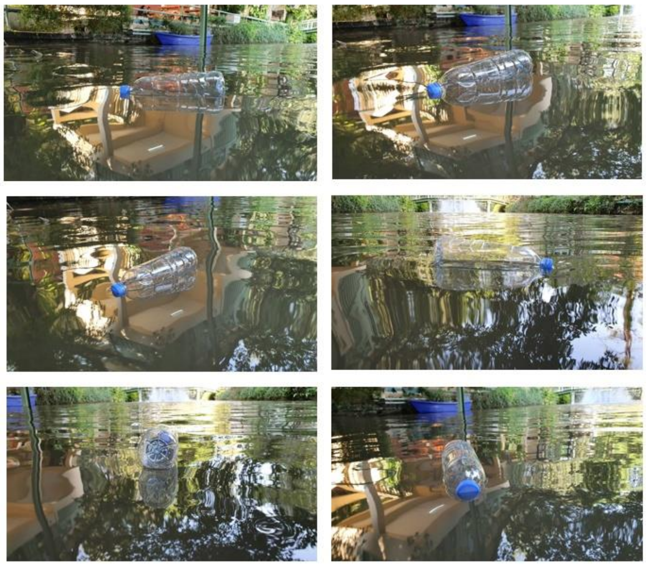

Fig. 7. The sample data of plastic bottle.

The robot client uses Wi-Fi module that included on the ESP32 board for communicating to the central server and LINE application. The message and image that sent to LINE Notify were shown in Figure 8.

Fig. 8. An example of message to LINE Notify.

IV. RESULTS AND DISCUSSIONS

In this experimental, the low-cost auto robot was setup and tested into two scenarios, both stationary mode and cover mode. The results show in Table I.

Table- I: Result of testing auto robot

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

Considering to four indicators, the accuracy came from the accumulative of true positive and true negative then divided by a total number of tested cases. The scenario in cover mode has more efficient for floating garbage collection than the stationary mode by average mean at 98.0% and 94.4% respectively. There has two indicator has the same accuracy: 'Floating garbage classification' and 'Floating garbage collecting'. The floating garbage classification indicator was process by a central server. Thus, the accuracies are the same value or nearest values. The floating garbage collecting indicator is the process of grabbing the floating garbage in front of the robot, it uses the same mechanism to handler the garbage.

According to the 'Floating object detection' and 'Movement cover area defined' indicator, the stationary mode has some weakness about floating object position which is nearest the rim of water pool. Moreover, the corner of the water pool is a blind spot, the signal from the ultrasonic sensor is out of reach to the floating object. In this case, it difficult to detect and collect the floating garbage at the corner for the big water pool.

V. CONCLUSION

The auto robot system was developed into two platforms. The IoT platform was built with the library in Arduino IDE based on IoT devices such as ultrasonic sensor, camera module, servo, and motors. The floating object is detected by ultrasonic sensor with combine the camera for snap an image then sent to web platform at central server. The floating garbage was classified on server with the Fast Approximation Nearest Neighbor algorithm. Thus, the auto robot can be realized in response to floating waste collection by grabbing and sent the messaging to user on social media application with the accuracy more than 94%. Moreover, the body of robot was assembled from the waste materials which are very low cost or near zero for gathering its. It could be said that the auto robot saves the cost and save the world by collecting plastic floating garbage.

For the future works, this system could be improving by: 1) to save the cost, the researcher will assembly the circuit from each electric device that worldwide in the electronics market, 2) to increasing the efficiency and saving power energy consumption, mixed mode of scenario could be applied between stationary and cover mode, 3) for the long-lasting of robot life, the solar cell and re-charging module system would be adopted, and 4) upgrading the bin system for collecting, counting, and alert to social media when the net bin is full.

ACKNOWLEDGMENT

I am grateful for the Institute for Research and Development, Suan Sunandha Rajabhat University, who supported and gave an opportunity in this research.

REFERENCES

1. World economic forum. (2019, January 9). We must stop choking the ocean with plastic waste. Here's how. [Online]. Available: https://www.weforum.org/agenda/2019/01/we-can-stop-choking-our-oceans-with-plastic-waste-heres-how
2. Surfers against sewage. (2019). Plastic pollution- facts and figures. [Online]. Available: https://www.sas.org.uk/our-work/plastic-pollution/plastic-pollution-facts-figures
3. TaTaTaTan. (2019, July 25). Life on LINE 2019. [Online]. Available: https://www.whatphone.net/news/pr/line-converge-thailand-2019-life-on-line
4. M. Abrams. (2018, May 16). Remote robot cleans trash from water. [Online]. Available: https://www.asme.org/topics-resources/content/remote-robot-cleans-trash-water
5. India Block. (2019, October 29). The ocean cleanup launches system to catch plastic waste in rivers. [Online]. Available: https://www.dezeen.com/2019/10/29/ocean-cleanup-interceptor-river-plastic-pollution
6. M. A. Yakoubi, and M. T. Laskri, "The path planning of cleaner robot for coverage region using Genetic algorithms," Journal of Innovation in Digital Ecosystems, vol. 3, no. 1, 2016, pp. 37–43.

7. R. K. Bharathi, T. S. Banupriya, and S. Jeyapriyanga, "IoT monitory system based smart trash management," International Journal of Engineering and Advanced Technology (IJEAT), vol. 8, no. 6S2, 2019, pp. 195–197.
8. D. V. B. Pragna, D. L. Reddy, and SVS Prasad, "IoT driven automated object detection algorithm for urban surveillance system in smart city," International Journal of Engineering and Advanced Technology (IJEAT), vol. 8, no. 6S3, 2019, pp. 1687–1991.
9. LINE. (2019, October 30). LINE Q3 2019 earnings results. [Online]. Available: https://scdn.line-apps.com/stf/linecorp/en/ir/all/FY19Q3_earnings_release_EN.pdf
10. A. Sengupta, V. Varma, M. S. Kiran, A. Johari, and R. Marimuthu, "Cost-effective autonomous garbage collecting robot system using Iot and sensor fusion," International Journal of Engineering and Advanced Technology (IJEAT), vol. 9, no. 1, 2019, pp. 1–7.

AUTHORS PROFILE

Sumitra Nuanmeesri was born in Ratchaburi, Thailand. She has obtained a Ph.D. in Information Technology at King Mongkut's University of Technology North Bangkok (KMUTNB), Thailand. She is Assistant Professor and lecturer in Information Technology Department, Faculty of Science and Technology, at Suan Sunandha Rajabhat University (SSRU) in Bangkok. She has taught web design and programming, object-oriented programming, and internet marketing. Her research interests include mobile application programming, information and image retrieval, big data and mining, machine learning, recognition of text and speech, supply chain management system, augmented and virtual reality development, and Internet of Things (IoT).