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RESEARCH ARTICLE

Development of Water Surface Mobile Garbage Collector Robot

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ABSTRACT

This paper presents a prototype of Water Surface Mobile Garbage Collector Robot built in motivation to educate the people to love and monitor the health of our rivers by collecting the trash themselves using mobile robot. The garbage collector is designed aimed for the cleaning of small-scale lakes, narrow rivers, and drains in Malaysia. The navigation of the robot is controlled using wireless Bluetooth communication from a smartphone application. The performance of the water garbage collector in terms of manoeuvring control efficiency and garbage collection load capacity was tested and evaluated. Based on the experimental results from a swimming pool, it can operate within a 4-metre range and collect 192 grams of small to medium sized recyclable garbage such as food packages, water bottles, and plastics in 10 seconds. It managed to float and navigate on the Panchor River within Bluetooth network range. A strong, lightweight and waterproof material is recommended for use for this water garbage collector. A proximity sensor or image processing technique for detecting garbage on the water surface may be studied and included in the future to enable a fully autonomous manoeuvring control system.

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Introduction

Rivers are vital to humans and other living things for a number of purposes, including acting as transportation hubs [1], providing shelter for riverine and aquatic flora and fauna, sustaining human life by providing freshwater, providing irrigation for plants, and maintaining the earth's humidity [2]. Today's population is rapidly increasing, and a number of rivers have badly affected by flooding [3]. According to a

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report, huge construction at upstream locations is one of the main factors leading to flash floods in the Damansara River[3]. Heavy rains can carry sediments from populated areas away, clogging drainage systems and triggering flash floods in some areas, especially urban areas [4].

Clogging drainage systems is also due to garbage [5], [6]. In developing countries, often found many garbage floating on the water such as plastic scraps, foams, tree leaves, and metal bottles. Accumulating dry waste floating on water surface can impede the drainage of water in city canals and cause flooding. Environment Minister B. Kambuaya, and the Central Bureau of Statistics records discovered garbage generation of 33 cities throughout the state in 2007 exceeded 132,192 cubic meters per day[6]. Not all the trash that was disposed of and deposited in landfill. A lot of garbage that was not properly managed were burned and thronged in the river [6].

The Klang River, which drains the megacity of Kuala Lumpur is one of Malaysia's most polluted rivers because it is often used as a convenient garbage dump [2]. Human negligence is the first to blame due to reckless disposal of food packaging, straws, or plastic packaging in public places [7]. Aside from that, garbage dump were also attempted from the squatter settlements[2]. As large agricultural areas are developed along rivers in Malaysia, settlements have traditionally sprung up along river banks and river estuaries across Malaysia's towns and cities with an estimated of 40,000 families in Klang River alone[2].

Pollution caused by plastic is unavoidable. It can occur anywhere. Malaysia is one of Asia countries affected by plastic pollution[8]. In one study, plastic waste accounts for 32 % of all garbage found in the Malaysian rivers[9]. According to a University of Plymouth report, half of at least 700 species of aquatic animals are threatened with extinction as a result of plastic waste[7].Aquatic lives are exposed to danger as they can be strangled by the plastic waste, suffocate and killed.

Steps of preventions has been made by governments for some countries. The local government of the District of Columbia in USA initiated Floating Debris Removal Program[10].The government of Jakarta made efforts to combat waste contamination in the river by introducing legislation on issues in Jakarta that prohibit business in floating markets[6]. Malaysian authorities are also attempt to a number of river restoration activities. The Department of Drainage and Irrigation put efforts in eliminating solid waste and silt from the Klang River, enhancing water quality and beautifying strategic stretches for recreational purposes [2].While there has been some change in the water quality, some rivers are still dirty [2].

Many studies are being conducted regarding easier ways of collecting garbageon the water surface[6], [8]-[21].This is to support the government's efforts in improving the condition of rivers, lakes, and waterways. Some garbage collectors are designed to be fixed[13] and movable[6], [8], [18]-[21], [9]-[12], [14]-[17].Mr. Trash Wheel, a solar-powered water wheel can effectively gather trash at the river's mouth until it enters the open water of Baltimore Harbor. It pulls garbage with the aid of a water pump powered by solar panels. It has collected 127 dumpsters full of trash and waste totaling 420 tons in its first 22 months of service [11]. The only downside of this system is that pumps must be easy to maintain and fix in order to stay in good condition.

Easy to maintain water surface cleaning robot can be realized if mechanical system with no electronics automation involved is used [14]. However, it requires huge manpower to move the cleaning boat pedals [14]. It is efficient in collecting huge amount of trash because of its large dimension. Another study utilized conveyor mechanism in its garbage collector design. It is a good design for reducing the manpower as the garbage were loaded onto the collecting tray automatically by motor control, however, high power consumption is needed to support the motor operation when the trash being loaded onto the collector increasing [11].

Combining the functionality of the smartphone with robotic features, controlled with a simple touch of a screen or different technologies integrated into an Android device enable remote and easy control. Some robot relies on Wifi network and bluetooth connection for getting the input command from the operator either using joystick, keyboard or from phone screen. In this paper, a water surface mobile garbage collector robot built with half-submerged propulsion feature and controlled wirelessly via Bluetooth network control system is proposed. The garbage collector aimed to collect garbage on the water's surface without the garbage giving burden to the body of the collector. The performance of the garbage collector was tested and evaluated in terms of manoeuvring control efficiency and garbage collection load capacity.

Methodology

The research methodology consisted of an explanation on the water garbage collector prototype and phone app development. Figure 1 shows the prototype of the robot. The robot twin hull construction allows it to remain afloat by using buoyancy chambers. DC geared motors with propellers attached will accomplish both of these goals. By turning on and off and reversing the polarity of the DC motors, the robot can turn left, right, backward, forward, left backward, right backward, left forward and right forward. The robot's operations and conditions are shown in Table 1.

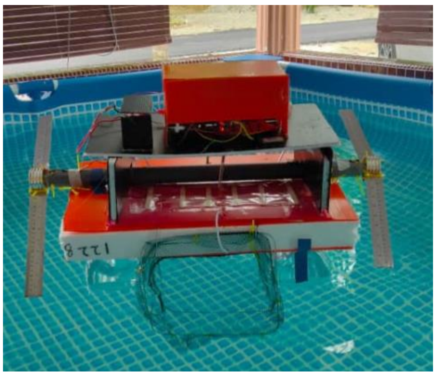

Figure 1. Showing the prototype of the garbage collector

Figure 2 shows the block diagram of the system. The robot will function based on the input directed from the MIT app installed in Android phone. The commands from the app are forward, backward, left, right, and break (stop). When the desired command is pushed, the Bluetooth transceiver from the cell phone will send signals to the Bluetooth module HC-05 connected to the Arduino UNO microcontroller.

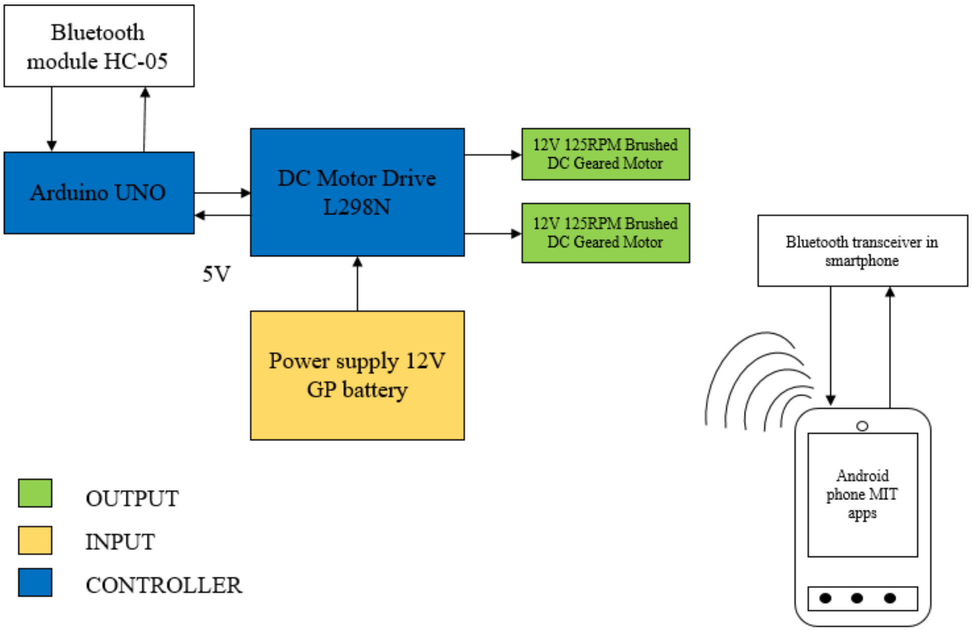

Figure 2. Showing the block diagram of the system

The microcontroller will then process the input signal through DC Motor Drive L293N. Next, output signals will be sent by microcontroller to the DC geared motors connected to the microcontroller. These motors will function according to the desired input sent from the MIT application. The GUI for MIT app as can be seen in Figure 3 was developed using MIT app inventor to provide interface for the user to control the water garbage collector remotely. When the status of the Bluetooth connection is established, the water garbage collector is ready to perform any desired operations from the phone app.

Table 1. Basic operations and conditions for the garbage collector system

Condition	Operation
Robot turns right	Speed motor right = OFF Speed motor left = ON
Robot turns left	Speed motor right = ON Speed motor left = OFF
DC motor break	Motor right OFF Motor left OFF
Robot move forward	Motor right on (+) positive polarity Motor left on (+) positive polarity
Robot move backward	Motor right on (-) negative polarity Motor left on (-) negative polarity

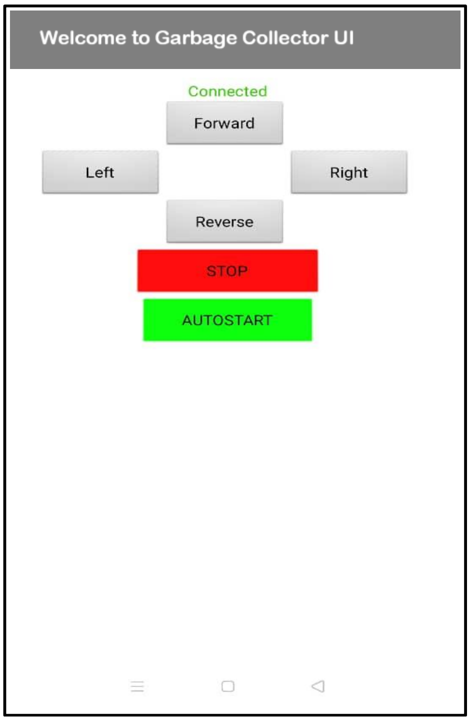

Figure 3. Showing the GUI of MIT app for water garbage collector.

Results and Discussion

The data from this research was gained as the result of water garbage collector experimental tests at two different locations. It was found that the water garbage collector is easier to control in a pool area compared to a river. This is because ripple waves affected the stability of the robot. The experimental results were separated into several parts, which were real data monitoring of the propeller speed outside water, garbage collector manoeuvring operation and garbage collection in pool and Panchor River.

Table 2 shows the propeller speed measured every 10 seconds using a tachometer. The laser from the tachometer was aimed at the propeller to measure propeller speed (no load) conditions. The detection of the propeller speed was executed three times for each operation. The lowest voltage battery drop after operations was 12.10 V, which is not much change from the initial voltage. The maximum propeller speed measured decreased with the decrease in voltage supply.

Table 2. Measurement results of propeller speed

Time of operation[s]	10		
Trial	1	2	3
Battery voltage before operation[V]	12.25	12.22	12.15
Battery voltage after operation [V]	12.23	12.21	12.10
Propeller speed in air (no-load) [rpm]	113.3 max	104.5 max	101.6 max

Figure 4 shows the movement of the water garbage collector in two conditions, forward and reverse. The travel distance from A to B is 2 meters. The 'Stop' button was pressed when it reached its desired location. Figure 5 and 6 both show rotation motion to reach for 90° clockwise and anti-clockwise direction.

Time of operation and battery voltage were recorded for all operations at each trial. The robot was operated for forward, backward, turning left and turning right motion and each operation were repeated for three times. The average time for water garbage collector to reach point B from point A, point A from point B, turn left 90° and turn right 90° was 9.9, 10.7, 2.8 and 3.3 seconds respectively. It was shown that the battery voltage decreased after each trial. It was considered a success when the propeller could operate in all operation modes and stop when the 'Stop' button was pressed. It was also shown from the table that the voltage decrement was not significant after every test.

Figure 4. Showing the point A and B

Figure 5. Showing the robot turning left 90°

Figure 6. Showing the robot turning right 90°

Table 3. Results when robot move forward, backward, turn left and right

Operation	**Move Forward**			**Move Backward**			**Turn Left 90-degree**			**Turn Right 90-degree**		
Trial	1	2	3	1	2	3	1	2	3	1	2	3
Battery voltage before operation[V]	12.1	12.1	12.1	12.0	12.2	12.2	12.1	12.1	12.0	12.0	12.0	12.0
Battery voltage after operation [V]	12.1	12.1	12.0	12.0	12.2	12.1	12.1	12.1	12.0	12.0	12.0	11.9
Time of operation [s]	9.4	8.5	11.6	11.4	11.0	9.8	3.5	2.3	2.8	3.0	3.3	3.6

Next, after the manoeuvring operation was tested, the garbage collector was operated to test for its functionality in collecting the garbage. Table 4 shows the time taken to complete garbage collection in a pool and Panchor River. The average time for the water garbage collector to collect garbage in pool area was 8.24 seconds. Six items were collected in the third trial. As can be seen from Figure 7, the quantity of garbage collection was different each time because at times, the garbage was far away from the water garbage collector and the user experience difficulties in collecting it when the garbage near the edge of the pool. As for the battery voltage before and after each operation, there was a slightly drop between every trial.

(a) (b) (c)

Figure 7. Showing the garbage collected in(a) first (b) second and (c) third trial

Table 4. Garbage collected in pool and Panch or River

	Operation in pool area (4.5 m x 2.0 m)			**Operation in Panchor River**		
Trial	1	2	3	1	2	3
Weight of garbage collected [g]	134	180	192	0	0	0
Battery voltage before operation[V]	12.05	11.98	11.97	11.92	11.91	11.87
Battery voltage after operation [V]	11.98	11.97	11.95	11.91	11.87	11.86
Time taken to complete garbage collection[s]	6.14	6.02	12.56	13.41	13.52	13.46

This experiment was tested in a calm river with small river current, as shown in Figure 8. The maneouvering was a success, however, no garbage was able to be collected after 13.46 seconds run time. The battery is still sufficient, but there was a time where the propeller became stuck to plants around the riverbank, therefore, the testing was stop for safety. Due to this issue, some future recommendations are proposed. The propeller should be covered to prevent it from stuck to river plants. The buoyancy chambers should only be placed at rear part to allow garbage flowing smoothly to the trash net. The proposed design for future improvement is shown in Figure 9. The proposed design consists of 5 main parts.

Figure 8. Showing the garbage collector in Panchor River

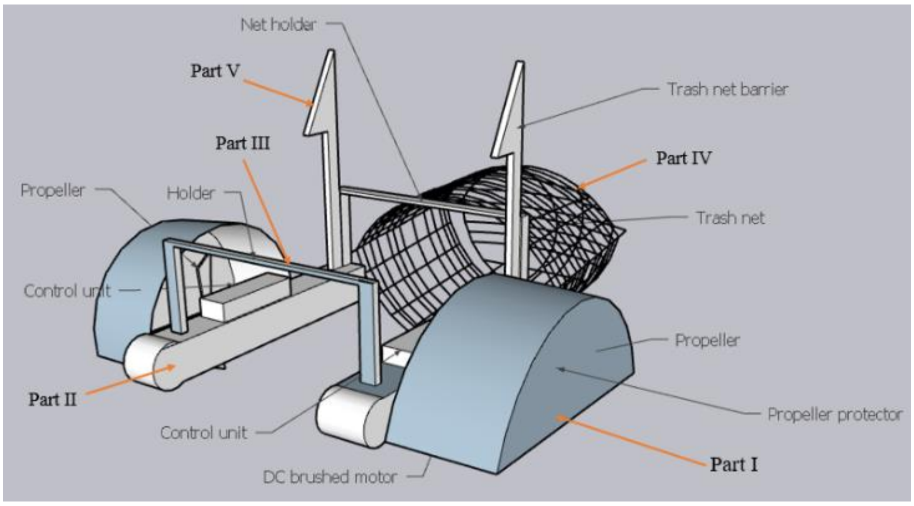

Figure 9. Showing the proposed design of garbage collector; propeller protector (Part I); control unit (Part II); robot rear parts connector (Part III); trash net (Part IV); trash barrier for preventing trash to come out (Part IV).

Conclusion

In this paper, a water garbage collector prototype was proved to be able to collect garbage on the water, float and partially immersed in the water's surface. After several experimental setups, it is proven that the remote navigation control of forward, reverse, turning left and right of the water garbage collector was successful using a smartphone application MIT. It managed to collect up to 192g of garbage within a 4.5-meter x 2.0-meter in pool area. In the future, the water garbage collector can be developed to automatically navigate without human operator and have garbage detection system. Every year from December to February, Malaysia usually experiences rainy days and floods, especially those reside in the East Coast of Malaysia. The prototype can be further improved to serve the purpose of eliminating the risk of flooding by using high strength and water proof materials for the collector body. A self-sustainable solar panel can also be used to support higher speed and torque DC motors.

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