Mini Amphibious Vehicle/Robot with Wireless Control System

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Abstract—This paper presents the prototype of a wireless-controlled mini amphibious vehicle/robot. The vehicle prototype can be controlled remotely via a wireless joystick communication system. The dimension of the mini amphibian vehicle is 45.5 cm length, 28.8 cm width and 16 cm height. The ground maneuver is actuated by two power window motors and the on-water maneuver is actuated by a DC brushed motor. The brushed motor is coupled with a propeller, where the thrust directions are steered by a DC servo motor. The performance test results present that the amphibious vehicle can make good maneuver on ground and on water surface by using a simple control algorithm implemented in a microcontroller, where the control guide signals are sent through the wireless communication system. The power testing presents that, the fully charged 3500mAh LiPO Battery can power up the mini amphibious vehicle to operate for 1.13 hours on ground movements and 0.7 hour for on-water surface movements. The maximum speed of the vehicle is 0.28 m/s on ground and 0.2 m/s on water surface. (Abstract)

Index Terms—Amphibious Vehicle, Wireless Control System, Control System, Microcontroller. (key words)

I. INTRODUCTION (HEADING 1)

Robotics have been interesting research topic in the past decade. The inventions of new technologies have supports the innovations in the robotic area. Robotics are widely used to help human or even replace the human activities in order to do some works. The work activity replacements are commonly due to accuracy, duration of work time and security reasons. In medicine, industries, space explorations and even in military, robots have shown their capability to replace a few human activities.

There are many types of robots, and the classifications are made based on specific applications or specific terms. According to the base condition, robot in general can be divided into tors, mobile robot, mini robot, humanoid robot, and many others according to the area of applications.

According to the mobility area of robots, the mobile robots can be divided into on-ground-movement robots, flying robots, and under-water robots [1]. Robots capable of moving on-ground and on-water and/or in-water are classified as amphibious robots. In addition, there are also many types of robot such humanoid robot, and many others according to the area of applications.

According to mode of operation, the vehicle or mobile robot can be divided into autonomous robot and manually guided robot. For specific applications, such as surveillance or observation, the guided vehicle robot is the best choice, because the survialence or observation procedures require data observation which can be optimally obtained via direct guidance from the surveyors or observers.

The research and development in the area of amphibious robot have been done so far [2,3,4,5,6,7,8]. A robot called AQUA robot is inspired from biological form has good capability on the foot movement and swimming. This Robot is developed between the year 1999 and 2003 by Ambulatory Robotika Lab in McGill University and York University in cooperation with University of Michigan, University of California at Berkeley, and Carnegie Mellon University [2]. The amphibious robot can be realized in by implementing rotor blades attached on the robot’s feet to provide swimming capability [3,4,7]. A biological inspired robot can also be developed for examples to mimic a fish form [5] or sea dog [8]. These types of robot form have very good swimming capability. In general, amphibious robots can be implemented with guided-propulsion technique [6], full-autonomy or semi-autonomy [7].

II. PROBLEM DEFINITION

The amphibious robot/vehicle can be operated on ground and on-water surface. For specific intention, the amphibious vehicle can move under water. This research is intended to realize an amphibious vehicle robot capable of moving on ground and on water surface in miniature size for prototyping purpose. The mini vehicle is hopefully able to be operated manually (non autonomous) via a wireless communication system in such a way that the mini vehicle can used in surveillance or observation of disaster environment especially water disaster condition.

The main design problem in the amphibious vehicle robot is the mechanical structure. The robot structure should be suitable for two areas of operation, i.e. on ground area and on-water or in-water area.

We also target to design the mini vehicle with minimum cost. Hence we have made a survey of the required tools and components to implement the vehicle such the design cost can be minimize.
III. CONCEPT AND HARDWARE MODEL

This amphibious vehicle is designed for surveillance applications, and can also be used for the observation of water disaster environment. In order to make on-water and on-ground maneuvers, the vehicle is modeled to resemble a military tank model. Figure 1 shows the frame model of the amphibious vehicle prototype. The vehicle/robot case is built from Aluminium material having the size of 0.5x0.5inch.

![Figure 1. The vehicle frame.](image)

Table 1. The vehicle dimension.

<table>
<thead>
<tr>
<th>Dimension (size)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Height</td>
</tr>
<tr>
<td>45.5 cm</td>
<td>16 cm</td>
</tr>
<tr>
<td>28.8 cm</td>
<td></td>
</tr>
<tr>
<td>5.2 Kg</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2 present the perspective view of the robot/vehicle for the front view, the side view and the top view, respectively. The robot/vehicle dimension of the vehicle is summarized in Table 1.

As shown in Figure 2(b) we use a belt held by 4 gears to transfer the mechanical torque from a Power Window Motor for each side. The vehicle is built in such a way that water cannot flow into the vehicle cabin.

As presented in Figure 2(c), we have mounted a receiver and its antenna on top of the vehicle. The vehicle can only move on water surface. Hence, allocating the antenna on the top body of the vehicle can be assumed save during robot/vehicle operation.

Figure 3 presents the important components including the electronic control unit for the amphibious vehicle. The vehicle components are summarized as follows:

1. Microcontroller as the main electronic control unit (ECU) from Arduino board, which uses Atmega328P microcontroller.
2. Two power window motors, which are used for on-ground maneuvering, one motor in the left-side and the other in the right side. We use a stereo steering system, where in order to make left-turn, the left motor turns in back direction, while the right motor turns in opposite (forward) direction. As well, to make right turn, the right motor turns in back direction, while the left motor turns in opposite (forward) direction. Turning on both motor in forward direction will move the vehicle straight forward.
3. One DC brushed motor is used to thrust the straight forward water movements of the robot/vehicle.
4. One relay used to drive two power window motors.
5. The other relay is used to drive the DC brushed motor.
6. One servo motor is used to steer the robot/vehicle movements to left or to right direction on water surface.
7. A LiPo Battery (3-cell) 11.1V having capacity of 3500mAh.
8. A receiver antenna mounted on the top body of the robot/vehicle.
9. A 6-12V voltage regulator (UBEC) to provide 5V voltage supply for the microcontroller.
10. A wireless joystick is used as the reference/guide input signal to control the robot/vehicle.

![Figure 3. The vehicle components including the electronic control unit for the amphibious vehicle.](image)
We use the Arduino IDE (Integrated Development Environment) software to develop the computer software program that would be embedded in the Arduino Microcontroller. The program is written in C/C++ computer language and compiled into machine code using the Arduino compiler.

V. Testing Results

We have tested the performance of the amphibious vehicle/robot on the ground and on the water surface. The performance test results present that the vehicle can be well controlled by using a simple control algorithm, where the reference or guide signals are sent via a wireless joystick.

A. On-water-surface performance test

Table 3 presents the test reference for the robot maneuvering on the surface of water. Before running the test in real plant, we have test the motor response to the joystick push button.

Figure 4 shows the test condition of the vehicle. The test environment is at a small lake in the area of our university. It seems from the test results that the vehicle can make good maneuvering on the water surface.

Table 3. On-water-surface test reference.

<table>
<thead>
<tr>
<th>Button</th>
<th>Robot/Vehicle response</th>
<th>Motor Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle</td>
<td>Forward</td>
<td>Rotate</td>
</tr>
<tr>
<td>Circle &amp; Left 1</td>
<td>Fast left turn</td>
<td>Rotate</td>
</tr>
<tr>
<td>Circle &amp; Right 1</td>
<td>Fast right turn</td>
<td>Rotate</td>
</tr>
<tr>
<td>Circle &amp; Left 2</td>
<td>Slow left turn</td>
<td>Rotate</td>
</tr>
<tr>
<td>Circle &amp; Right 2</td>
<td>Slow right turn</td>
<td>Rotate</td>
</tr>
<tr>
<td>Circle &amp; Triangle</td>
<td>Forward</td>
<td>Rotate</td>
</tr>
</tbody>
</table>
Figure 4. On-water-surface performance testing.

B. On-Ground Performance Test

Table 4 presents the test reference for the robot maneuvering on ground. Before running the test in real plant, we have test the motor response to the joystick push button.

Figure 5 shows the test condition of the vehicle. The test environment is undertaken on grass beside our university building. It seems from the test results that just like the on-water testing, the vehicle can make good maneuvering on ground.

Table 4. On-ground test reference.

<table>
<thead>
<tr>
<th>Button</th>
<th>Robot/vehicle response</th>
<th>Motor response</th>
<th>Left Motor</th>
<th>Right Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up</td>
<td>Forward</td>
<td>Motor</td>
<td>Forward</td>
<td>Forward</td>
</tr>
<tr>
<td>Down</td>
<td>Back</td>
<td>Back Motor</td>
<td>Back</td>
<td>Back rotate</td>
</tr>
<tr>
<td>Left</td>
<td>Left turn</td>
<td>Back Motor</td>
<td>Back rotate</td>
<td>Forward</td>
</tr>
<tr>
<td>Right</td>
<td>Right turn</td>
<td>Forward Motor</td>
<td>Forward</td>
<td>Back rotate</td>
</tr>
</tbody>
</table>

C. Speed Test

The speed test of the mini amphibious vehicle can also be undertaken where speed test data are summarized in Table 5. The speed test present that the vehicle can make straight forward movement on water surface at speed of about 0.2 m/s, and forward movement on-ground at speed of about 0.28 m/s.

D. Power Test

Beside the performance tests, the power tests are also made. The vehicle is powered by a 3500 mAh LiPO Battery. With fully charged condition, the battery can power up the mini amphibious vehicle to operate for 1.13 hours to make maneuver on ground, and 0.7 hour to make maneuver on water surface.

Table 6 and Table 7 present the power measurements by using battery having capacity of 3500 mAh. During the on-water-surface movement, the vehicle use the only one brushed motor. Hence the it requires only 3.7V to power the brushed DC motor as the thruster for on-water movement. The power measurement does not include the servomotor. During the on-ground testing, it requires 11.1V to power the power window motors.

VI. CONCLUSIONS AND FUTURE WORKS

A. Concluding remarks

This paper has presented a mini amphibious vehicle that can make maneuver on ground and on water surface. The mini vehicle is driven by four motors. Two power window motors are used to make maneuver on ground, one DC brushed motor is used to thrust the vehicle during on-water-surface maneuver, and a DC servo motor is used to steer the vehicle movement direction on water surface.
The mini amphibious vehicle does not move autonomically. It is controlled or guided by users using a joystick, where the guiding reference signals are sent via the 2.426-GHz wireless communication system. The experimental test presents that the vehicle can be controlled at maximum of 20 meter distance, in accordance with the transceiver specification data.

The speed test present that the vehicle can make straight forward movement on water surface at speed of about 0.2 m/s, and forward movement on-ground at speed of about 0.28 m/s. The straight back movement can also be made at the same 0.28 m/s as the forward movement.

The power testing presents that at the fully charged condition of the 3500mAh LiPO Battery, the mini amphibious vehicle can be operated for 1.13 hours for on-ground movements and 0.7 hour for on-water surface movements.

B. Future Works

There are some improvements that should be made in the future for the better operation as described as follows:
1. The use of GPS system such that the mini amphibious robot can be operated and controlled from further location (more than 20 meters).
2. The use of better actuator having better torque capacity such that the mini amphibious vehicle can make better maneuvering.
3. The use of higher better capacity such that the mini amphibious robot can be operated for longer time.
4. The optimization of the component specifications and material weight for the vehicle’s frame and body. Thus the vehicle will have optimal total weight to do its best maneuvering.
5. The use of multi-sensor system to sense the acceleration, speed or vehicle orientation, such that a reliable feedback control system can be applied in the current system.

REFERENCES