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Remote Controlled Aerial and Aquatic Robot for Surveillance Operations

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Abstract: The Remote Controlled Aerial – Aquatic Robot for Surveillance Operations is a waterproof quadrotor equipped with LiPo batteries, brushless motors, electronic speed controllers and an Arduino microcontroller. Flying and Swimming is possible with the help of manual ballast attached to the robot's main frame. Experiments show that mechanism has 89% reliability rate in air and 48% in water. Although water movement is limited to minimal forward, up and down movements and human intervention is still needed for maintenance, this robot will enable the initiative and start-up of fusion mechanisms in the country.

Key Words: quadrotor; aerial vehicle; underwater vehicle; surveillance; waterproof

1. INTRODUCTION

Air and water travel navigation have always been limited. The depths of the sea and height of the atmosphere are distant things that no one can freely explore. Scientists have been reduced to progressing and experimenting on things found in land. In the new generation of technology, a new type of robot answering the limitations occurring due to the fact that vehicles have limited mobility and view will be created. Making the machine have the capability of maneuvering in two environments is both a challenge, as well as an innovation

A good technological venture would be a union of cross-breeds: aerial and aquatic robotics. Developments regarding autonomous aerial robots have been reduced to aircrafts such as planes and rockets, while aquatic robots are limited to submarines and boats. Moving from an out-of-the-box, philosophy and as part of the assessment of robots, a new thesis will be formulated which will deal in the design, fabrication and analysis of an aerial aquatic robot.

Considering that this robot will enter a multi-disciplinary field in robotics, integration of different aspects of electronics, mechanical and programming techniques will be used in developing the output. It is also considered a developmental research regarding possible advancements in navigations and improvements of frame. The selling point of this apparatus is its specializations in two terrains which opens a more extraordinary possibility as here in the Philippines, the most extensive research in relation to aerial or underwater vehicles is the wired snake created by MAPUA. Further advancement can be seen in the creation of a remote controlled quadrotor which will pave the way for progress in different areas of security, rescue, military and industry.

2. SYSTEM DESCRIPTION

In order for the mechanism to adapt to aerial and aquatic environments, several objectives must be adopted:

2.1 Objectives

For the robot specifications:

- Maximum volume of 3 cm3
- Maximum size of 3m x 3m x 3m
- Maximum weight of 5 kg
- Robotic shell withstanding the pressure exerted when submerged and lightness for flight
- Wireless and waterproof
- A 15 minute initial setup time must be given for the mechanism. An estimate of around 10 minutes would be needed for change of robot operating mode, from aerial to aquatic environments, and vice versa

For the robot components:

- Microcontroller as a processing unit
- RF signal that acts as a link for the control station and the root. Remote control and process data will be used
- Transceiver circuitry to process the signal
- Stationary camera for surveillance purpose. This must have a 510 x 492 resolution for live stream in air and recording possibility for water
- DC motors for movement adaptability
- Lithium based batteries as power supply

For the robot function:

- Designed for swimming at a maximum depth of 1.5 m and flying for a maximum height of 1.5 m

Capable of moving in the x-y-z coordinates

2.2 Conceptual Framework

In creating an aerial-aquatic system, maneuverability and controls can only be identified through balance between mechanical, electrical and processing systems. From a remote controlled system, the mechanical components consisting of the main frame (or body) and the motors make up the skeleton of the robot. With this skeleton, a brain for full command processing through the microcontroller and power supply will act as the knowledge bank of the system. Helping these are the incorporated sensors and external surveillance system.

While taking this into account, Figure 1 shows us that there are some concepts to be considered in creating the quadrotor.

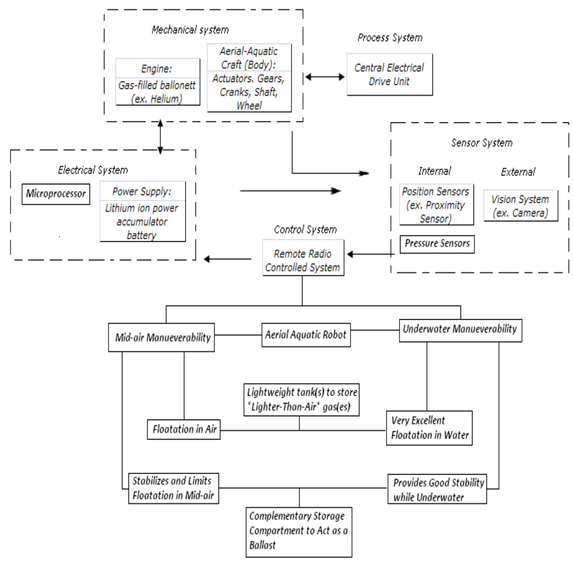

Fig. 1. Aerial – Aquatic Concept

Take note that it has initially been noted that the system follows the Archmiedes principle "the buoyant force does not depend on the weight or shaped of the submerged object but on the weight of the displacd fluid"[47]. This suggests that the body should be light enough for it to course through air but heavy enough to sink underwater.

3. DESIGN CONSIDERATIONS

In the overall construction of the mechanism, a number of considerations regarding specifications and components are to be made.

The following factors were considered with regards to finalizing the design: programming difficulty, electronic difficulty, design flexibility, innovation, complexity and attainability at current skill. For more information, see Table 1.

Table 1. Final Weight Breakdown

	MANTA RAY	TURTLE	PUFFERFISH	FLOATING SUBMARINE	DOUBLE DEVICE	QUAD
Programming	5	3	3	2	2	4
Electronic	5	4	5	4	5	3
Mechanical	5	4	4	5	5	4
Innovative	5	2	3	3	1	5
Attainability	1	3	3	3	4	4
Cost	5	4	4	5	5	4
RANK	3	2	2	3	2	1

Different evolutions have been experienced throughout the design consideration. Figure 2 represents the thought process in the design concepts formulated at the start of the project. As a result of successive experiments performed on different theories and designs, the quadrotor was formulated. A quadrotor was the most suitable as it would require less mechanical and electronic expertise as opposed to other designs (e.g. biomimetic robot).

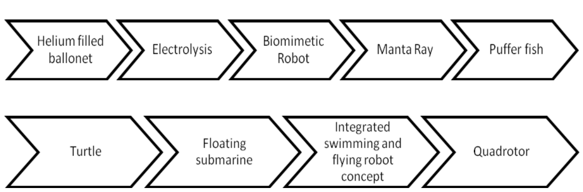

Fig. 2. Evolution of Design Concepts

Concerning appropriate materials, flight and swim theories added into the configuration, the Quadrotor system is the most suitable for our application.

3.1 The Quadrotor

It was calculated that the robot should weigh less than 2000 grams to meet the necessary take-off weight. This dictated that frame be less than 700 grams. Different materials are also considered. Below is a detailed explanation of frame designs that was used for the quadrotor, see Figure 3.

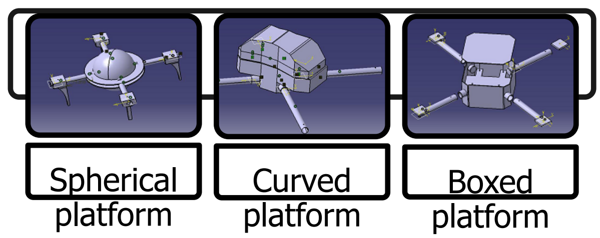

Fig. 3 Frame Designs

In the end, the boxed platform was used as the key element was provided in this design – light enough to fly and waterproof underwater. Most of the electronic components are also of a boxed-shape nature making the design have the right fit; however, this does not answer the possibility of having the robot dissipate water easily. Designs in which the internal structure was also considered, see figure 4:

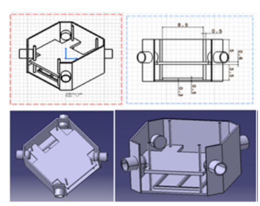

Fig. 4. Double Layered Platform

Overall, a double-layered platform was chosen to reduce the weight and height of the robot. All the electronic components became compact. The greatest disadvantage however is that because the LiPo battery is placed below, extra setup time is needed in changing batteries.

The final quadrotor setup with the weight breakdown stated in table 2 became a boxed double-layered platform mechanism.

Table 2. Final Weight Breakdown

	Actual weight
Electronic Components	1377g
Frame	593g
Ballast	3023g
Total Weight	4993g

3.2 Quadrotor Configuration

QUAD consists of a singular aerial-aquatic quadrotor and a ground station. The frame of the body is made of propylene material that allows the robot to be waterproof, assuring safety of all electronic components and polycarbonate screen and arms for the camera viewing, and holding the motors respectively.

It is able to maneuver in both air and water environments through the use of 4 BL2215/25 brushless motors, 40A electronic speed controllers and 8 x 3.8 counter-rotating propellers. Its life is dependent on 2 2200mAh LiPo batteries. A separate 800mAh LiPo battery is used for the microcontroller.

The system communicates to the user through a transceiver with the use of a remote control, whose main function is to control the 4 signals: throttle, yaw, roll and pitch. The core of the mechanism is an Arduino microcontroller circuit, coupled with an Aeroquad shield that incorporates a gyro, accelerometer and magnetometer sensor. The microcontroller runs by PID controls, interfaces with the sensors, and supervises the system.

In order to properly allow the robot flight and dive functions, specific parameters must be known: (a) gyroscope measuring angular velocity (b) accelerometer measuring acceleration, (c) magnetometer measuring magnetic field strength, and (d) the direction cosine matrix values are corrected and orientations are determined. This allows the quadrotor to facilitate two modes: acrobatic and stable.

Acrobatic mode is when the transmitter sticks control angular rates about each axis:

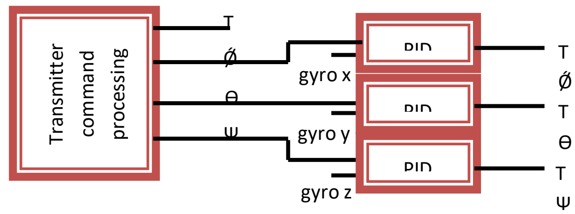

Fig. 5 Acrobatic mode

Stable mode is when the transmitter sticks control banking and yawing angle:

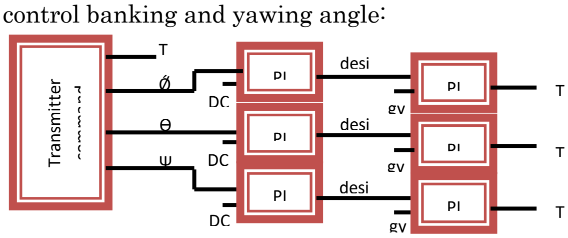

Fig. 6 Stable mode

Once the user has already accustomed itself with both modes, transmitter can now process its commands.

The ground station consists of a laptop computer, to interface with an aircraft through a transceiver. This allows live stream video surveillance when in flight and recording capability underwater through a GUI program interface.

4. EXPERIMENTATION

The reliability of the aerial-aquatic robot for surveillance operations has yet to be examined. With these trials, the group will be able to present the efficiency and deficiency of the system.

There are two types of quadrotor setups to be used all throughout the experimental process: (1) Quadrotor in Air and (2) Quadrotor in Water. Quadrotor in air is the robot as itself containing the main boxed frame, 4 ESCs, 4 brushless motors, 2 pairs of counter-rotating propellers, 2 batteries, and the microcontroller. On the other hand, the quadrotor in water needs the attachment of manual ballast in order to maneuver properly in aquatic environments.

4.1 Depth and Height Test

In order to verify maximum range and performance of quadrotor with respect to the z axis, this test is needed. Quadrotor is first tested in aerial environment at different height levels multiple times: 1.5m, 3m, 4.5m and 6m . Results were recorded according to grade description: (a) Good – quadrotor behaved how pilot commanded it (b) Fair – quadrotor seldomly does not act how pilot wants it to behave and (c) Bad – quadrotor does not behave how the pilot commands it. As shown to Table 3, the quadrotor functions at 94.44% at a 5 feet height considering that antenna is stretched. The other 5.66% of the time, the quadrotor was not responding the way the pilot commandeered it. Performance relatively goes down as it increases its height.

Table 3. Final Weight Breakdown

Distance	Performance
1.5m	94.44%
3m	97.22%
4.5m	69.44%
6m	25.00%

A similar test was done for the aquatic environment at depth levels: 1.2m, 1.5m, 1.8m and 2.4m.

Table 4. Depth Test in Water

	2m away from the controller
1.2m	100.00%
1.5m	89.29%
1.8m	67.86%
2.4m	28.57%

Movement underwater is at 89.29% allowing 1.5m depth. Like in air, distance is directly proportional to performance of the quadrotor.

4.2 Maneuverability in Air

This test defines whether the mechanism can move properly in the x and y axis considering aerial functionalities. A point of destination is marked through 50cm x 50cm boxes. Quadrotor is then observed if it deviates. The hovering capacity using forward motion is at 89% while sideward motion is at 70%. Most of the trials that did not arrive at the supposed location were due to calibration issues and pilot error.

4.3 Maneuverability in Water

Similar to the previous test, the performance of the quadrotor must also be measured in water. Destination points will be marked in the swimming and quadrotor will be observed if it reaches said destination. It is given that if vessel makes a 180 degree turn, trial is marked as failed.

Aquatic simulations have been limited to steering the quadrotor to its destination point. Results is said to have 45% accuracy. This is not possible without multiple retrievals and human intervention of the assistant.

5. CONCLUSIONS

A remote controlled robot able to maneuver in aquatic and aerial scenarios was designed and constructed in a quadrotor unit with a waterproof case, assuring stability and toughness. Mechanism can be stated to be durable as it has attained 91.67% leak-proof status at a 40 minute mark.

Mechanism is able to fly due to microcontroller and its PID controls; however, problems such as banking angle and calculation of accelerometer are beyond the control of the researchers. Distance from robot to surveillance system or remote control, range, and setup directly affects the performance of the quadrotor in terms of height and depth.

This wireless robot is able to move along the x-y-z coordinate system. It is said to attain a passing mark in movement adaptability in aerial scenarios but improvements could be made regarding maneuver in aquatic areas as an inclusion of manual ballast is needed to properly propel the robot up and down. Pilot control becomes a variable in the accuracy rating as numerous sessions are required to master and control the quadrotor. Overall, the quadrotor represents the successful flight of the first-ever remote controlled aerial-aquatic vehicle.

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