Safe Landing of Autonomous Amphibious Unmanned Aerial Vehicle on Water

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Automatic landing system for Autonomous Amphibious Unmanned Aerial Vehicle (AAUAV) hovering on water surface is proposed. AAUAV comprises of inculcating multicopter and hover craft configurations to be served as an aerial vehicle as well as hovering on water bodies. The placement of hovercraft on the water surface, after the multicopter carries the hovercraft as a payload to the particular location in water, has to be done precisely so as to keep the vehicle safe from getting into the water. For this purpose, the propulsion system of the multicopter and the hovercraft are controlled with an aid of information from Ultrasonic sensor. The distance above the water surface is measured using ultrasonic sensor and after a threshold level of distance, a control signal from Arduino will be sent to respective brushless DC motors of both the configurations to hover the vehicle above the water surface. Preliminary experiments are conducted and test results confirmed that the developed control will be utilized in controlling AAUAV for water sampling applications.

Keywords: - **Amphibian uav, multicopter, hovercraft, arduino, ultrasonic detector, autopilot,**

1.   Introduction

The AAUAV (Autonomous Amphibious Unmanned Aerial Vehicle) has been considered to have two separate vehicles. One Hovercraft and the other is multicopter. Both are flexible in terms of attaching with one another and detaching too. This shows that it can be operated separately as a multicopter and hovercraft as per the requirement. The main mission for being an Autonomous Amphibious UAV, both needs to be attached together. While flying to some point, the hovercraft is considered to be the payload of the Multicopter. So, for that time period of flying, the hovercraft will not be in operation and when the hovercraft is in operation, the multicopter will not be in operation. Both can be operated simultaneously whenever it is necessary. Some issues are expected to be faced while switching the propulsion system operation from Multicopter to Hovercraft as it will be difficult to identify from the ground station that whether the hovercraft has touched the water surface or not and this necessarily requires some sensor(s). Consequently, the switching from the multicopter propulsion system to the hovercraft lift propulsion can be done precisely. Failing in that may end up the hovercraft being placed little bit more inside the water resulting in the water entering in to the skirt portion and the bit more may damage any of the electronic components.

The increasing use of the Unmanned Aerial Systems has forced to add some techniques and precise technologies to vehicle so that it can easily avoid the crashes due to the obstacles coming on the path while flying on its mission path autonomously. For this purpose, sensors such as ultrasonic detector, Laser rangefinder, etc. are used[i]. The same sort of sensors can be selected from the pool of options and used to identify as well as get notification regarding the placement of the hovercraft on the water surface carefully for this AAUAV vehicle. The capabilities of laser based sensors are much higher to the capabilities of ultrasonic sensors, nevertheless ultrasonic sensors are highly capable of giving a precise reading when they are perpendicular or almost perpendicular to the surface, becoming a practical solution to measure the distance with objects over and under the quadcopter, being one of these objects the floor, meaning this that the sensor can be used to measure the flight altitude when approaching the landing zone[ii]. The solution for the above mentioned difficulty can be overcome by using the ultrasonic detector with Arduino. Along with the detection of the distance above water, the switching ON and OFF the hovercraft lift motor and multicopter motors, respectively can be done in order to operate the hovercraft at the right time resulting in Hovercraft perfectly hovering on the water surface.

2. Autonomous Amphibious Unmanned Aerial Vehicle system

The benefit of AAUAV is, it can normally be used for water as well as aerial applications that can be achieved using Unmanned Aerial Vehicles. The AAUAV's are quite different in terms of its operation from other normal UAVs. The application that can be worked on with the help of AAUAV's includes water testing, collection of water sample, aquatic research, cargo delivering, and surveillance, etc. For these applications, a multicopter and a hovercraft can be used together to attain a successful mission. Both, hovercraft and the multicopter, can be separated and easily be operated as per the mission requirements.

Figure 1 – 3D Design of AAUAV (Hovercraft plus Multicopter)

The multicopter used here is a hexacopter (having six bldc motors) and can be modelled with carbon fibres for its low weight – high strength properties. The centre section contains all the electronic components and the multicopter landing gears are designed in such a way that it can be attached with the top of the hovercraft using some fixtures. The hovercraft structure can be made by using ply and balsa wood while the electronic components mainly includes one duct fan and one bldc motors are used for the lift and the thrust production in the hovercraft respectively. Both the vehicles, separately and simultaneously, can be operated with the help of remote controls. The main reason behind combining the two vehicle is based on the advantages and disadvantages of both the vehicles. The hovercraft can be operated on land and water but it has got a little demerit that it cannot go much farther on its own propulsion system. Moreover, it may not get stable operation during heavy sea states as well as in steep slopes[iii]. Whereas, the multicopter can be operated in air only. But, it can go far depending upon the propulsion system and the communication system we add in the model. But, it cannot be operated on the water for some major application except surveillance and that is its main disadvantage.

So, to overcome the disadvantages like, not traveling in long range and under heavy sea states (in hovercraft) and cannot be operated on water (in multicopter), the two vehicles can be combined to perform for a mission successfully. The hovercraft along with the multicopter can go far and can be operated on water by flying from one point to the other whenever required in the mission application (in case the hovercraft has to go for some long distance).

3. Controlling AAUAV using Arduino and Autopilot System

3.1. Controlling motors using Arduino

The arduino, when programmed for a bldc motor, can operate and control more than one bldc motors simultaneously. This can be done by connecting arduino with motor via a connection given to the ESC and a battery is connected with the ESC to power up the motor. The motor is connected with the output of the ESC. The connection has been done as per the figure 2.

3.1.1.   Controlling one motor using Arduino

In one motor control procedure using Arduino Uno, the connection setup is done between the Arduino Uno and Motor using Electronic Speed Controller (ESC) and thereby ESC connected with the battery. The below program is being uploaded on the Arduino Uno while the motor is connected in the lift duct of one of the prototype models of the hovercraft.

Program

```
#include <Servo.h>
Servo esc_signal;

void setup()
{
  esc_signal.attach(12); //Specify here the pin number on which the signal pin of ESC is connected.
  esc_signal.write(30);  //ESC arm command. ESCs won't start unless input speed is less during initialization.
 delay(4000);       //ESC initialization delay.
}

void loop()
{
esc_signal.write(90);   //Vary this between 40-130 to change the speed of motor. Higher value, higher speed.
delay(30);
}
```

Steps

The connection steps for the single motor connection are as follows:
1.   Program Arduino with Arduino IDE
2.   Connect the motor to the output of ESC
3.   From the 3 pin cable coming out of the ESC, connect the Brown cable to the 'GND' pin on Arduino.
4.   Connect the Yellow cable to any digital pin on Arduino. We connected it on digital pin 12.
5.   Connect the '+' & '-' of battery to the '+' and '-'wires of ESC respectively.
6.   Give power supply to the Arduino by connecting the cable with Computer/Laptop and Arduino.
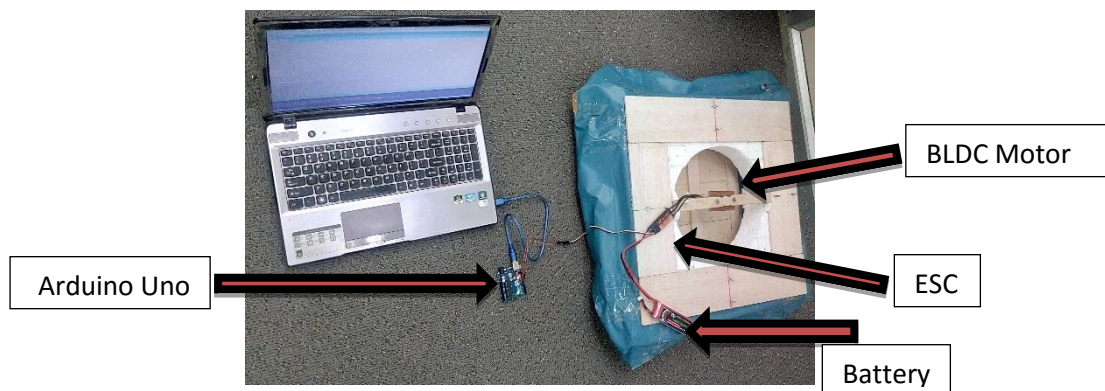7.   Upload Program to the Arduino board [iv]

Figure 2 –Arduino connection with motor

3.2. Controlling AAUAV motors using Arduino

The Arduino board, as described for the control of one motor, can be used to control multiple motors simultaneously[v].

```
#include<Servo.h>
```

```
Servo esc1;
Servo esc2;
Servo esc3;
Servo esc4;
Servo esc5;
Servo esc6;
Servo esc7;
                            //initializing ultrasonic pins
#define echoPin 1
#define trigPin 2
                            //max n min range of ultrasonic sensor
int maximumRange=60;
int minimumRange=16;

long duration,distance;

void setup() {
                            //servos attached to different pins in arduino
esc1.attach(12);
esc2.attach(11);
esc3.attach(10);
esc4.attach(9);
esc5.attach(8);
esc6.attach(7);
esc7.attach(6);
esc1.write(30);
delay(3000);
pinMode(trigPin,OUTPUT);
pinMode(echoPin,INPUT);
Serial.begin(9600);

}

void loop() {
 digitalWrite(trigPin,LOW);
 delay(2);
 digitalWrite(trigPin,HIGH);
 delay(10);
 digitalWrite(trigPin,LOW);
 duration=pulseIn(echoPin,HIGH);
                                    //converting time into distance
 distance=(duration/2)/29.1;
                                    //condition when the distance will be recorded
if(distance>60)
{
Serial.println(distance);
Serial.print("cm");
esc1.write(90);             //speed at which you want to rotate
esc2.write(90);
esc3.write(90);
esc4.write(90);
esc5.write(90);
esc6.write(90);

}
else if(distance<=60)
  {
```

```
    Serial.println(distance);
    Serial.print("cm");
    esc1.write(90);          //speed at which you want to rotate
    esc2.write(90);
    esc3.write(90);
    esc4.write(90);
    esc5.write(90);
    esc6.write(90);
    esc7.write(90);
    delay(60000);
  }
 else if(distance<=16)
{
Serial.println(distance);
Serial.print("cm");
esc7.write(90);              //speed at which u want to rotate
}
else
{
  printf("none of condition works");
}
}
```

The above programming has been done in the arduino IDE software.

3.2.1. Program Explanation

1. In the Initialization, 7 Servo objects (i.e. ESCs) have been created as we have 7 motors to control and we can control different servo at same time. The two ultrasonic has pins, echo and trigger pin, have been connected and defined to arduino. The maximum and minimum distance has been initialized defining the duration and the distance.

2. The Setup includes the defining of the servo connections and after the delay of every 3 seconds, it will be transmitting the acoustic signals. Also, in the setup, the trigpin defined will help us in getting information about the distance.

3. In the loop, initially, the sensor making it on and off for some duration. The equation distance = (duration/2)/29.1; that's required to be added to calculate or convert the speed of sound through air in terms of time duration to centimetres. You'll have to divide it by two as it travels to and fro.

4. In the output, the moment the ultrasonic detects and calculates the distance less than 60 cm, as per the arduino programming, the lift motor of the hovercraft will be turned on to create the air pressure inside the skirt so that it can easily float on the water without facing any failure in landing. In the second step of this procedure, the arduino turns off the 6 motors of the hexacopter, the moment ultrasonic detects the distance to be at 16cm. In this duration of coming down from 60cm to 16 cm the hovercraft will get an enough time to get the required or the maximum amount of the air pressure so as to float on the water.

3.3. Controlling AAUAV motors by interfacing Arduino and Autopilot

The other way of controlling motor for safe landing is, by interfacing arduino with the autopilot. In this case, the motors are connected to the esc and motor and lastly to the Autopilot. Whereas, this autopilot will be connected to the arduino. The ultrasonic sensor, connected with the arduino, will send the information regarding the altitude of the vehicle. As distance described in the above program, the same distance will be followed. But the concept of controlling changes here. So, the arduino is going to get the information once the vehicle distance from the water surface is 60 cm. The moment it decreases from 60 cm, the arduino sends an information to operate the hovercraft motor. This will happen till the distance is less than 60 cm and more than 16 cm from the water surface. The moment the distance decreases below 16cm, the multicopter motor stops. This all the controlling happens with the help of the information provided by the ultrasonic to the arduino and thereby sent to the autopilot system with which the motors and all the other controls are connected.
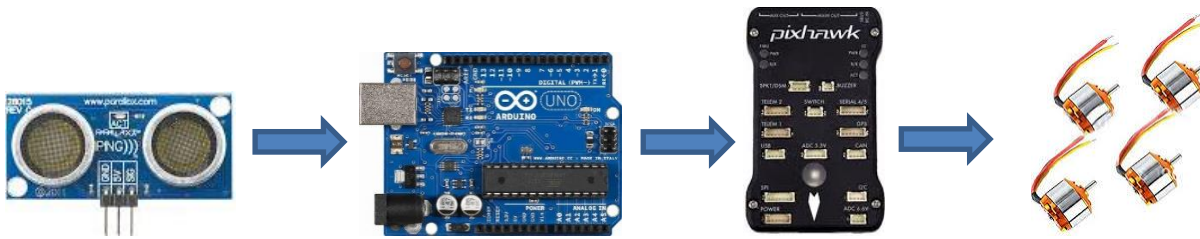
Figure 3 – Block diagram of arduino and autopilot connection

The above diagram shows the connection that connects the ultrasonic sensor with the arduino through its 3 – pin connection viz. ground, Vcc and signal. The output from the arduino will be given to the Pixhawk autopilot which has a pre-programmed and calibrated motor stability function. With this all the motors will be connected and programmed in such a way that it can be controlled as per the information being transmitted from the ultrasonic sensors to the arduino and to the Pixhawk.

Conclusion

The transition of multicopter mode into hovercraft configuration of amphibian vehicle to hover along water bodies is achieved through controlling the motors of respective configuration. A typical distance of 160mm is set as a threshold value of ultrasonic sensor and triggering of propulsion system is carried out. A simple hover craft is developed and control of the system is performed using Arduino. The test result shows that, the developed algorithm is used to control AAUAV effectively. Integration of autopilot to achieve the multi-mode configurations of AAUAV will be deployed in real time water sampling applications to collect the water samples and perform in-situ water quality analysis.

References

i. Nils Gageik, Thilo Muller, Sergio Montenegro: Obstacle detection and collision avoidance using ultrasonic distance sensors for an autonomous multicopter

ii. Pandya Garvit Kalpesh, "Distant mission UAV capability with on-path charging to increase endurance, on-board obstacle avoidance and route re-planning facility", International Journal of Computer Engineering in Research Trends, 4(1):10-14, January 2017. [Innospace-2017: Special Edition]

iii. www.griffonhoverwork.com/whyhovercraft

iv. https://www.instructables.com/id/Interfacing-Brushless-DC-Motor-BLDC-With-Arduino/

v. Anurag Singh Rajpoot, Namrata Gadani and Sagar Kalathia, "Development of Arduino based Quadcopter", International Advanced Research Journal in Science, Engineering and Technology, Vol. 3, Issue 6, June 2016