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Amphibious Drone, Which Can Land and Take Off From Any Water Body Safely

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ABSTRACT
Unmanned aerial vehicles (UAV), also referred to as drones are emerging field in Computer Science and Engineering with applications in military systems, delivery services, emergency relief and evacuation. One of the primary challenge in UAV is take-offs and landing safely. The landing base of the drone should be made of light weight products. Centre of gravity plays an important role in balancing and efficiency of drone in process of landing and take-offs in water and land respectively. We propose unique design of amphibious drone that apply landing area detection system using machine learning and image processing technique. This system compares the suitability of various features (RGB Color Model, HSV Color Model, LBP, Edge Density) in determining a suitable drop-off point. Classification on these features will be carried out using Support Vector Machines (Linear, Polynomial and RBF Kernel). After imaging and remote sensing, the data collected will then be processed and predicts the conditions for safe landing. While landing, we are going to shift the Center of Gravity of drone by moving the metal weights downwards so that it can float stably and when we take-off we shift the Center of Gravity upwards as needed.
Keywords:- *UAV,CG,Hydraulics,Machine learning*

I. INTRODUCTION

Development of Unmanned Aerial Vehicles is now a major research area in robotics, with applications in numerous fields such as defense, delivery systems, etc. A UAV (or a drone) is an aircraft without a human pilot aboard, whose flight may be controlled either autonomously through on-board computers or remotely by a pilot on ground.

A UAV is not operated for sport or hobby and does not transport passengers or crew. Since a drone operates autonomously or remotely, it eliminates risks such as pilot safety, and increases the effectiveness of the operation. Precision farming, Customs and Border Control, Firefighting, Emergency Relief, Emergency Landing of Aircrafts- are some of the applications that require landing of autonomous vehicles. This work can be adapted to meet the constraints of any of the above-mentioned applications which primarily deals with finding safe landing areas or take-off points.

Detection of surface water through multi-spectral data is an important topic in remote sensing. In recent years, various approaches have been developed to detect water on the ground, especially for small water bodies such as streams. Spectral index is one of the most popular directions in water detection, taking advantage of differences of land covers in spectral reflection.

On the other hand, machine learning methods are also frequently applied in identification of water bodies. Given appropriate and adequate training samples, supervised learning shows a good performance, for instance, support vector machine (SVM), neural network, and decision tree. However, unlike to other land covers, surface water could produce diverse spectral response from large rivers to small streams, which makes training samples be hard to find adequately. Unsupervised learning is difficult to apply directly on water detection because it separates data in clusters rather than identifies the specific land cover types. Moreover, since ground truth is unavailable in some cases, it is of great importance to detect water automatically in a fully unsupervised context. As spectral signatures do not always provide enough information in classification decisions, multi-sensor data fusion has become another promising aspect in land cover classification. Plenty of approaches have been proposed to combine information from various sensors. In general, fusion of multi-sensor data can be classified into three different levels: the pixel level, the feature level and the decision level. Fusion in the pixel level consists in considering different original data from multiple sensors as the data from one signal source with single resolution, making data more informative than an individual source. In the feature level, several features (e.g. edges, lines and texture information) are extracted from different data sources so that they can be combined into one or more features maps, rendering more information than original data. Fusion in this level is of great importance when numerous spectral bands are available, avoiding analyzing each band separately. Decision level fusion combines the classification results from multiple sensors to generate a final decision.

II. RELATED WORKS

There are some related works, like -

- Detection of landing areas for unmanned aerial vehicles[1]
- An automatic water detection approach based on Dempster-Shafer theory for multi spectral images[2]
- DJI is working on HEX H20 pro, SARA H20 RTF. These two are their amphibious
- Drones.[https://www.quadh2o.com/]

The largest drawback is – in most of the cases the Drones are unstable in water for waves and current of water body and if we consider a situation of sea shore's large waves, these Drones are very much unstable there.

III. PROPOSED MODEL

(1) DESIGN OF DRONE:

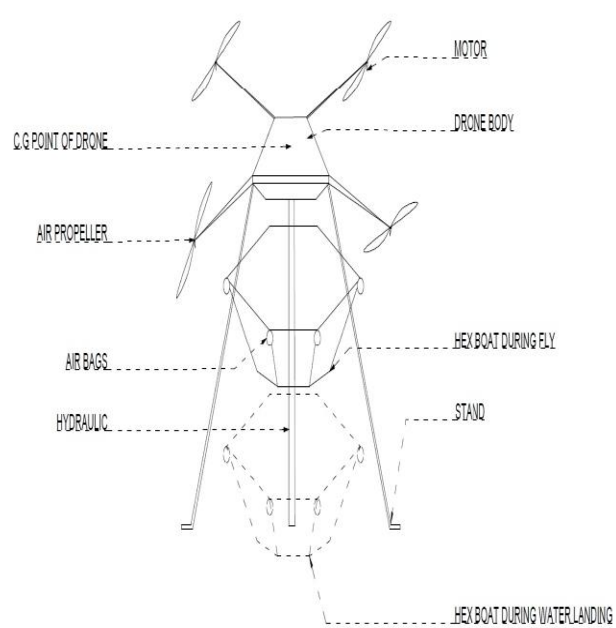
The design in figure 2 consists of 6 components:

1. Drone- A drone will be used to carry payload (like medicines, necessities etc.). It will be capable of carrying weight more than its own. It has four stands and a hydraulic attached to it.
2. Stand- It helps drone to land in ground surface.
3. Hydraulic- Attached to drone and boat this plays the most important part in this design. It is responsible to shift the center of gravity by making the boat go away and near the drone when needed.
4. Hex Boat - This is a unique design. It looks like a buoy. A hexagonal structure is given to resist the water current to some extent. It has a cap like shape in bottom to float efficiently. It is made of light weight balsa wood and is coated with waterproof paint to make it waterproof.
5. Pontoon balls – These floatable balls do not sink. Six of these balls are placed in the hexagonal edges of the Hex boat. It helps if excessive weight is applied.
6. Camera – to capture the images of water surface.

It is must to have weight greater than that of the drone. The weight can be the carrier load provided for supply or could be implicitly given.

After the drone is designed, system description given in figure 1 can be implemented by Anaconda, which is a free open source distribution

Figure 1– design of the drone



of the Python and R programming languages for large-scale data processing, predictive analytics, and scientific computing, that aims to simplify package management and deployment. Using Python we can implement the SVM for supervised machine learning which can predict the safe landing on water body.

When the drone is in air and preparing to land on water, it will first capture images of the water surface. Using those images it will first analyze and compute if the area is good for landing or not. It checks if the depth of water is sufficient to land the drone by support vector machine. When the drone finds an area to land, it shifts the Hex boat down using a hydraulic pump. Then slowly the drone lands in water.

The Hex boat is designed to maintain the stability of drone in severe conditions. When the drone needs to take off from the water, it is lift off to some height using the power of its rotor. Then the Hex boat is pulled up towards the drone with the help of hydraulic pump.

(2)MATHEMATICAL MODEL:

When an object is placed in a fluid, the fluid exerts an upward force on it which we call the buoyant force.

This force is equal to the weight of the liquid that is displaced by an object. This is also known as Archimedes' principle. The unit for the **buoyant** force (like other forces) is the Newton (N).

Buoyant force=(density of liquid)(gravitational acceleration)(volume of liquid)

$F_{buoyant}=\rho g V_f$ **----- Eq (1)**

Where,

ρ=density
g=gravitational force
Vf=volume of fluid

Weight of the liquid displaced = upward buoyant force:

$V_s \times D_w \times g = V_b \times D_b \times g$ ---- Eq(2)

$V_s/V_b = D_b/D_w$

Vs = Volume of displaced liquid
Dw= Density of water
g= gravitational constant
Vb= Volume of balsa wood
Db= Density of balsa wood

Assumptions:

Following are some of the assumptions :

Approx. mass of the Drone= 4.5 kg(including hex boat)
Density of Balsa wood=130 kg/m^3
Volume of Drone(Vb) = m/D = 0.0346m^3
Applying the assumptions in Eq(2)

Vs= 4.5 x 10^-3

Force applied to balsa wood(upwards): from eq(1)

Fb= 45N

Force downwards due to weight(m x g):

F=45 N

IV. EXPECTED OUTCOME OF THE MODEL

a. EFFICIENCY

From the above calculations we understand that weight of water displaced by drone and upward buoyant force comes in equilibrium, the model successfully floats in any water body.

b. SCALABILITY

However if the weight of the water displaced is more than buoyant force, that is drone weighs is more than volume of the water(density<1), pontoon ball placed at each edge of hex-boat acts as a backup and does not let the model sink in any condition.

V. DRONE SPECIFICATION

5.1 FRAME: It is the structure that holds or houses all the components together. They are designed to be strong and lightweight.

We are using the frame with the diameter of 580mm. and overall weight of the frame is 650 gm. The material we are using is carbon fiber.

5.2 ROTORS OR MOTORS:

The purpose of motors is to spin the propellers. Brushless DC motors provide the necessary thrust to propel the craft.

For our project we are using the motor EMAX-3315, which is a 650 kV motor. This motor can provide a thrust of 20 A, i.e 1650 gram using 15 inch propellers

5.3 BATTERY – POWER SOURCE:

LiPo (Lithium Polymer) batteries are used because it is light. NiMH (Nickel Metal Hydride) is also possible. They are cheaper, butt heavier than LiPo. LiPo batteries also have a C rating and a power rating in mAh (which stands for milliamps per hour).

For our project we are using 4 cell 12000 mAh LiPo (Lithium polymer) battery.

Endurance-

The Endurance of the Drone with this battery will be 30 to 40 minutes. The flight time may vary for different payload.

5.4 ESC- Electronic Speed Controller:

The electronic speed controller controls the speed of the motor or tells the motors how fast to spin at a given time. For a quad copter, 4 ESCs are needed, one connected to each motor.

For our project we are using the ESC of 30 emp, BL series.

5.5 PROPELLERS:

A Quad copter has four propellers, two "normal" propellers that spin counter clockwise, and two "pusher" propellers that spin clockwise to avoid body spinning.

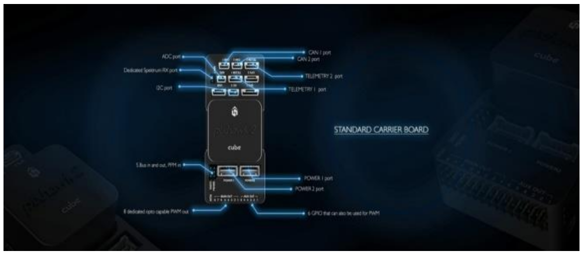
For this project we are using 15 inch carbon-fiber propellers, which helps to provide a up thrust of 1650 gram altogether.

5.6 RADIO TRANSMITTER AND RECEIVER: The radio transmitter and receiver allow to control the quad copter. Four channels for a basic quad copter is required .Using a radio with 8 channels, so there is more flexibility is recommended. Quad copters can be programmed and controlled in many different ways but the most common ones are by RC transmitter in either Rate (acrobatic) or Stable mode. The difference is the way the controller board interprets the orientations feedback together with the RC transmitter joysticks.

In Rate mode only the Gyroscope values are used to control the quadcopter. The joysticks on the RC transmitter are then used to control and set the desired rotation speed of the 3 axes, though if the joysticks are released, it does not automatically balance again. This is useful when the Quad copter is required to do stunts like tilting it a bit to the right. The speed of the 4 motors will be adjusted automatically and constantly to keep the quad copter balance.

5.6 FLIGHT CONTROLLER BOARD (FCB):

The flight control board is regarded as the brain of the quadcopter. It houses the sensors such as the gyroscopes and accelerometers that determine how fast each of the quadcopter's motors spin.



Here in our project we are using the Pix-Hawk 2.1 board. This board is quite suitable for this project as per our survey.

VI. METHODOLOGY

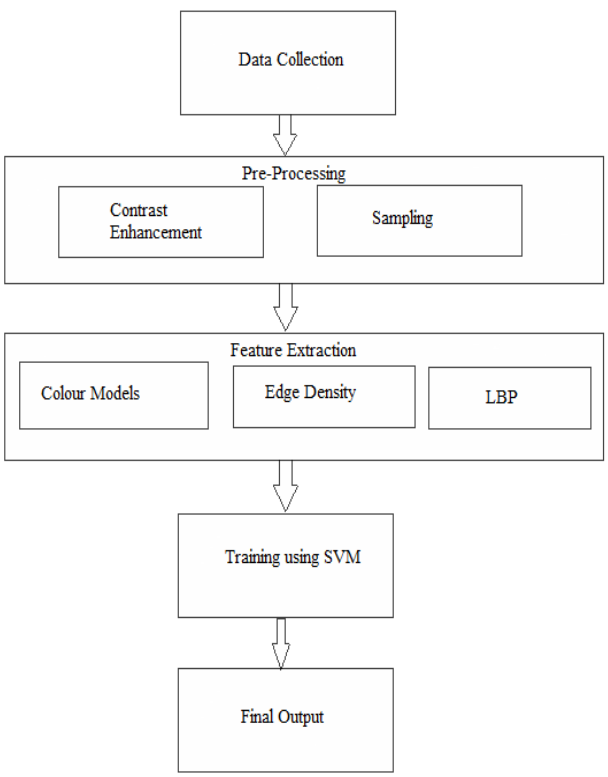


Figure 2. Flow-diagram of proposed method.

The proposed system description is given in Figure 2. The following sections detail each step of the detection process.

A. Data Collection: We are using the images captured from the drone camera as our input images. From the collected dataset of images, out of which 2/3 will be used for training, while the remaining will be used for testing.

B. Pre- Processing: The images obtained in the data collection stage will be pre-processed to better suit our problem. To ensure the uniformity among the images, we can resize the image to 256X256. The images will then be sampled into small square patches with an edge size of 16 pixels (standard value). Our system implement feature extraction on each extracted patch and classifies each image patch as either safe or unsafe.

C. Feature Extraction: For our proposed system, we will be using 5 individual features (RGB color model, HSV Color Model, Local Binary Pattern, Canny Edge Detection, Sobel Edge Detection) initially and analyze their results. Later, we will implement different combinations of these features to obtain significantly better results. The features used are explained briefly:

1. RGB and HSV Color Model: In the RGB color model, the images are represented using their red, green, and blue components, while in the HSV model, Hue, Saturation and Value (brightness) is calculated. Research has shown that since the HSV model is motivated by the human visual system, it is better suited for describing image colors as compared to the RGB representation. Further, experiments conducted have shown that the RGB model is quicker, but inaccurate, as compared to the HSV model. In our system, color features are calculated by averaging the RGB and HSV values and generating a color histogram.

2. Local Binary Patterns: Local Binary Patterns have proven to be effective texture descriptors in image classification. LBP is effective largely due to its low computational complexity and high robustness to

variations. It is calculated by comparing each pixel with its neighboring pixels.

3. Edge Density: For a given image patch, the edge density feature measures the average edge magnitude in that region of the image. The edges in the image will be calculated using two edge detection algorithms- Canny Edge Detection and Sobel Edge Detection. Thus the edge density of each patch will be calculated by counting the number of pixels in the patch that are part of edges. We will also consider the edge densities of surrounding patches while training the model.

D. Training: We will use the supervised model using Support Vector Machine (SVM) which includes two steps: the learning step and the classification step. In the learning step, data associated with already known label is utilized to train parameters in the model. The classification step allows to predict labels of new data based on the learning function. Large water bodies, such as rivers or lakes, are often easy to be detected, while smaller ones like streams tend to be confused with other land covers since not sufficient information is supported to represent their own spectral reflections. In this case, lacking information could increase imprecision and uncertainty of classification, causing unsatisfying results.

E. Expected Output: During this testing stage, each patch of the image is identified as safe or unsafe. The results for all 256 patches of each image are combined to provide a combined image output. The result expected after this combination is the final binary image that displays landing areas using 1 (White) and unsafe areas as 0 (Black).

VII. CONCLUSION AND FUTURE WORK

Drones are the future of technology. In near future most of the works will be done autonomously by drone. So the drone must be smart and capable enough to complete it's tasks.

We have proposed a system to detect suitable landing areas when an image of the overall landing area is available by using machine learning algorithm – SVM as well as we have made a drone design that is going to be stable while landing in the water after landing safely. It can take the era of drone to another level by serving as surveillance, Payload carrying(we can say medicine carrying or some important goods carrying), life saving, army needs etc.

We have also taken care of the stability of drone while flying to make it more reliable.

Some works that can be implemented in future-

With the HEX-Boat we could attach a rotor, which would help the drone to navigate in water.

Installation of solar panel or any other battery system can be done to increase the time of operation and efficiency of this drone.

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