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DESIGN, FABRICATION AND SIMULATION OF HEXACOPTER FOR FOREST SURVEILLANCE

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ABSTRACT

Unmanned Aerial Vehicles (UAV) is being suggested for critical applications like border surveillance, difficult mapping and atmosphere studies. Especially in military application, it saves money and lives of soldiers compared to manned military aircraft. Major problems in the forest border region are human – animal interaction and animals poaching. With the help of the complete surveillance, these problems can able to solve. Nowadays the surveillance around the forest has been carried out by forest officers. Monitoring the forest through officers is not complete surveillance, due to the natural factors of human beings may be the error will occur in the monitoring. To avoid this problem, the monitoring of the forest region is to be covered by UAV. Animal activities and large forest coverage area is difficult task to handle in forest monitoring, so a normal UAV is not suitable for this process, hence Hexacopter is a better solution for this monitoring because it's a have unique characters like high operational speed, more stability, etc. The proposed Hexacopter would be capable of the vertical take-off and landing feature like a rotary wing aircraft and also the six propellers provides the more stability and high manuvering capability during the monitoring process. This Hexacopter payload is about 1kg and total dimension is of 500mm x 500mm, the main purpose of this hexacopter is to provide the wealthy surveillance in the forest and gives an alert about the animal's exact position and takes necessary action. The estimated design of hexacopter has been modeled by CATIA. With the help of the MATLAB 10.0 the image processing has been carried out in order to find the animal detection, animal hunting and animal counting. The emergency system will be activating in account of error animal matching percentage output from image processing.

Keywords: animal - human interaction, animal poaching, forest, hexacopter, surveillance.

INTRODUCTION

Hexacopter features

The multirotor platform used in this paper is a hexarotor. In this hexarotor, central hub is for payload attachment and six propellers are fixed in the end of the separate aluminum arms, which are attached with central hub with an angle of 60^{O}. Central hub is also provides home for avionics components together with battery. The propellers of the hexacopter are individually driven by an electric motor, which is attached at the end of the arm separately. All the propellers have fixed pitch blades, which increase the potential of the UAV, which makes craft more comfortable with low vibration. Essentially, this model has all of the same major advantages of a quadcopter with a lot more added in safety, which means that a controller will be able to safely land the drone even if one motor is damaged [1]. The maneuver controlling of the hexacopter depends upon its six propellers. Each propeller produces an upward thrust by pressing air downwards. Since the foundation of the upward force is situated exterior of the center of gravity, differential upward force can be used to rotate the UAV. The rotation of the motors and propellers also generates a reaction twisting force, which are acts opposite direction of the rotation. Since three propellers are spinning in clockwise direction, and the other three are in counter clockwise direction so the net torque when all rotors have equal speed is zero. They are four basic movements: throttle, roll, pitch and yaw. These control signals, in this paper denoted virtual control signals, are mapped to different ways of changing the propeller speed. The speed of every entity rotor is the sum of the six control signals involvement to that particular rotor [2].

Table-1. Comparison of quadcopter and hexacopter.

	Quadcopter	Hexacopter
Ground speed	25 m/s	35 m/s
Rate of climb	10 m / s	15 m / s

LITERATURE SURVEY

Multirotor UAVs are eager way for innovative research works and the usage of multirotor UAVs in real time applications are gradually increasing nowadays due to its unique characters. Of the literature surveyed, classification of multirotor UAV's and its control & guidance divides into either indoor application using remote control or outdoor applications using Global Positioning System (GPS) based navigation [1]. In this paper an outdoor application based hexacopter proposed for forest monitoring. In this hexacopter detailed study divided into parts, which are selection criteria of a hexacopter components and payloads and animal detection techniques [3].

Selection criteria of a components and payloads

For forest monitoring, hexacopter is a potential replacement for human-beings and normal UAVs because

it can able to fly in a region of atmospheric environments, also able to operate frequently as well as efficiently track the animals loaded with full payloads. To execute the forest monitoring process through hexacopter the system should 1) easily adapt with fundamental programming skills, 2) gather and provide error free data, 3) operate autonomously, 4) provide sensor payload with low probability of failure, 5) more safe for field use, 6) easily access back to home option after each flight, 7) be able to operate more tactical missions [4].

Selection of suitable components and payloads is the only way to create the hexacopter systems more reliable for forest monitoring. Overall weight is one of the important parameters for hexacopter component selection. The maximum weight of proposed hexacopter is 1.5 kg, so the thrust required should be double (1.5 kg * 2 = 3 kg) of the weight of the hexacopter. In hexacopter totally six motors are equipped for stability and high operational speed so each motor should give 500 g thrust based on thrust and weight combination. Propellers design depending parameters are Motors specification, pitch of the propellers blade and the amount of thrust produced by the individual propeller. The best suitable propellers for this paper is 5x4.5" propeller, which can be able to produce the 500 g thrust. The selection of battery plays a vital role in hexacopter design and practical simulation also its selection is depending upon the motors capability, the amount of weight and the specification of propellers. For this work the best suitable battery is 3 Cell LiPo battery because of its specification completely satisfy the basic requirements of Hexacopter. Each motor individually attached by the Electronic Speed Control (ESC) and its used to control the speed of the motor and also simultaneously to produce the pitch, roll, yaw motion of the hexacopter [5].

Generally all the aircraft equipped with an IMU (inertial measurement unit) which is nothing but, a device that provides accelerometers, gyros and an implanted controller to incorporate information to present accurate data on the aircraft manoeuvring details as well as accelerations in all direction. GPS is most ideal for outdoor applications and presents a positional fix. GPSs suffer from GPS drift, which is solved either by combing data with that from an IMU or by using a differential GPS system. Vision based navigation systems regularly take up either a single or stereo cameras. Stereo vision lends itself to estimating the distance of the features from the cameras using observation, while other distance sensors such as ultrasound are needed for single camera systems [6]. In this paper payload used for hexacopter is infrared sensor, camera, weather sensor, and laser scanners.

Animal detection techniques

Animal detection is valuable in deterrence of animal- human interactions also increase the human and wildlife safety, finally decrease the animal poaching. In this paper there is survey of different animal detection and recognition techniques are studied such as animal matching, edge based matching, skeleton extraction. With the help of the complete study about UAVs image processing, the high probability of success methods is selected for forest surveillance.

Intelligent Video Surveillance (IVS) system

In IVS, there are basically six components. These components are Acquisition, Transmission, Compression, Processing, Archiving, and Display.

Dynamic object detection techniques

In computer vision applications, categorizing dynamic objects from a video surveillance clips is a critical task. Recognize the animal from the portion of a video with the help of background subtraction which differs significantly from a background model.

Feature extraction

In dimensionality reduction family, extraction of feature is a special technique which comes under image processing. When the input to an animal detection algorithm is excessively large to be progression and it is suspected to be notoriously redundant then the input will be renovated into a diminished symbol set of features.

Template matching

In digital image processing Finding a small parts of an aerial image compared with template image is called as template matching. In signal processing, cross-correlation is evaluated of resemblance of two waveforms as a time-lag function [7].

COMPONENTS SELECTION

Multirotor performance parameters and avionics parameters are the important in literature survey and the relation between these two kinds of parameters was found out which will help in improving the overall efficiency of the hexacopter and also make the design process easy. The complete theoretical design approach for a hexacopter has been followed with known techniques and it should satisfy the standard approaches. The parameters considered were: speed (m/s), range (km), endurance (hr), gross weight (kg), service ceiling (m), wingspan (m), length (m), and payload (kg). Hexacopter component has been selected in two ways. One is first fix the weight of the hexacopter and chooses the component in that weight range. Another one is without fixing weight choosing component of Hexacopter and finally estimate the weight. For this work the selection components are based on second method which means, primary design consideration is hexacopter components and secondary consideration is hexacopter weight [8].

Components selected for hexacopter

1) Sensor: MARG - Particle filter based sensor which includes magnetic, angular rate, gravity.
2) Battery: 3S battery -LIPO
3) Motor: Brushless DC motor
4) Propeller: APC 1047
5) Microcontroller: 1. AT mega 121; 2. Gumstick Microcomputer (600 MHz ARM cortex-A8)
6) Frame: Aluminium Alloy, composite landing bed

7) Camera: Pin-hole type camera

Weight estimation

The overall weight of a hexacopter has been estimated. Weight estimation is one of the important parameters in the hexacopter theoretical calculation and also its plays vital role in selection of hexacopter components. Based on the top up approach, the entire design calculation is done.

- Payload weight : 0.5 to 1.5 kg
- Weight of propeller : 0.1 to 0.3kg
- Weight of the motor : 1.2 kg (6*0.2)
- Weight of the battery : 0.5 kg
- Weights of the Hexa Structure : 1 kg
- Overall weight (approx) : 2 to 2.25 kg
- Height of the landing bed : 7 cm

Design and manufacturing of Hexacopter

Figures 1 and 2 shows the preliminary CAD diagram of a haxacopter with different views. Figure-1 shows the front view of hexacopter with camera arrangement. Figure-2 shows the high operation speed mode of a isometric view of hexacopter for provide more stability and survives in the forest regions. This CAD diagram has been modelled by CATIA.

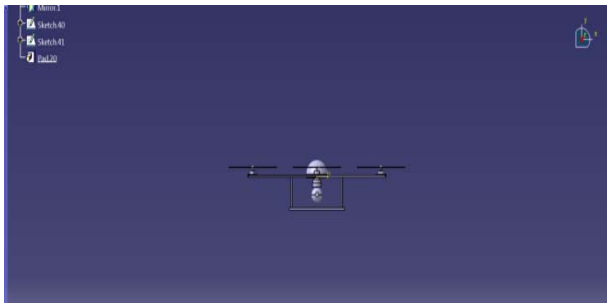

Figure-1. Front view of hexacopter.

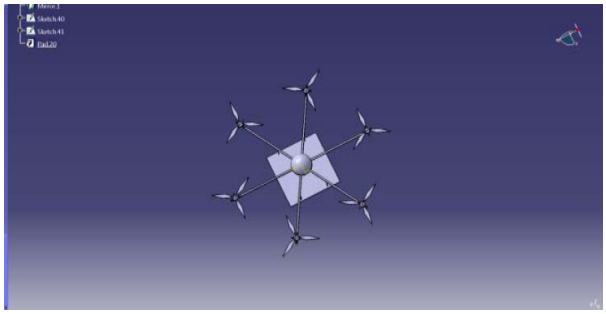

Figure-2. Isometric view of hexacopter.

Figure-3 shows the prototype of hexacopter with the same equipments and same dimensions which are calculated from theoretical approach.

Figure-3. Top view of hexacopter.

RESULTS AND DISCUSSIONS

Currently the use of UAVs in the world has emerged because of their ability to operate in dangerous locations with assurance of safe location of their crew members. Smaller UAV should have greater maneuverability and flexibility so it can able to operate more critical tactical missions such as rescue, surveillance, tracking for enemy positions, etc. also capable of carry a primary sensors, payloads and systems such as GPS, video camera, microprocessor. Real time problems and critical environments are will be technically covered by smaller UAVs compare to larger one. Similarly in this paper also deals smaller UAV (Hexacopter) with advanced techniques for forest surveillance in which, animal detection and recognize its action is plays a vital role. Here the real time animal detection and monitoring to be performed by image processing. Image processing is a method to renovate an image into digital code and execute simulations on it, in order to get an enhanced image or to extract needful details from the image.

Image processing in forest monitoring is a critical application, in which the clarity of the image and pattern able to fluctuate due to lighting and exposure conditions, the images can be first normalized. Color, shape and animal detection and clarification are the fundamental attributes to symbolize and catalog the images. These abnormal features of images are extracted and implemented for a similarity check among images. Image indexing is not good in terms of space and time in traditional methods so it generated the improvement of the new technique [9]. The stages of the new technique are image–pre-processing, extraction of features, animal detection and recognize its action, finally warning system activation. In this paper, standard vision features such as different animal color, natural images, animal shape and techniques such as noise removal, whitening, data normalization and the use super-pixel to group similar neighboring pixels have been used. The main work of this algorithm is to differentiate the animal edge from the natural image and takes the needful action when animal aerial images capture in the camera. Once animal images confirmed with database then matching percentage results calculated with the help of feedback control system for activate alert system via advanced sensors [10].

Steps involved in image mining process area

Step 1: Read captured aerial image from reference image database. Step 2: Pre-process the aerial image to enhance the clearness of the image. Preprocessing contains recognition and labeling of the objects contained in the images using an image query processing algorithm. Step 3: Perform transformation of images into database. In the pre-stored table row and columns stands for a pixel and features associated with same pixel respectively. Finally total number of pixels in an image represents number of rows in the image processing. Step 4: Feature extraction has been executed after the confirmation of database table estimation. Step 5: Implement mining using suitable data mining techniques to identify suitable patterns after the features extraction. Step 6: Finally, the outcompeting outlines are calculated and inferred to attain the details, which can be applied to forest surveillance [11]. In this paper, image processing has been carried out in two different conditions, which are different angles and animal images. In both the cases image processing has been simulated by MATLAB with the help of reference images and aerial images are taken from the internet. In future case, the aerial images to be captured and aerial surveillance will be efficiently covered by autonomous hexacopter.

In future, Surveillance System using Autonomous Hexacopter (SSAH) can be used as flexible test platform to perform surveillance. It can easily perform autonomous flights and eliminate the presence of workers in the critical positions as well as overcome the human error factors. This Hexacopter can be used in surveillance, monitoring of forest regions that are large distances from the base station and also takes the necessary action with the help of warning system such as create the sound and send the animal position images to the ground control station [8]. Steps involved in this SSAH algorithm are, Step 1. New aerial view of forest capture; Step 2. Compare the new forest capture with reference image; Step 3. Detect the amount of animal presences in the image; Step 4. If the result is more than 50% then activates the warning system [12]. The figure 4 clearly explains the step-by-step procedure of animal detection by hexacopter.

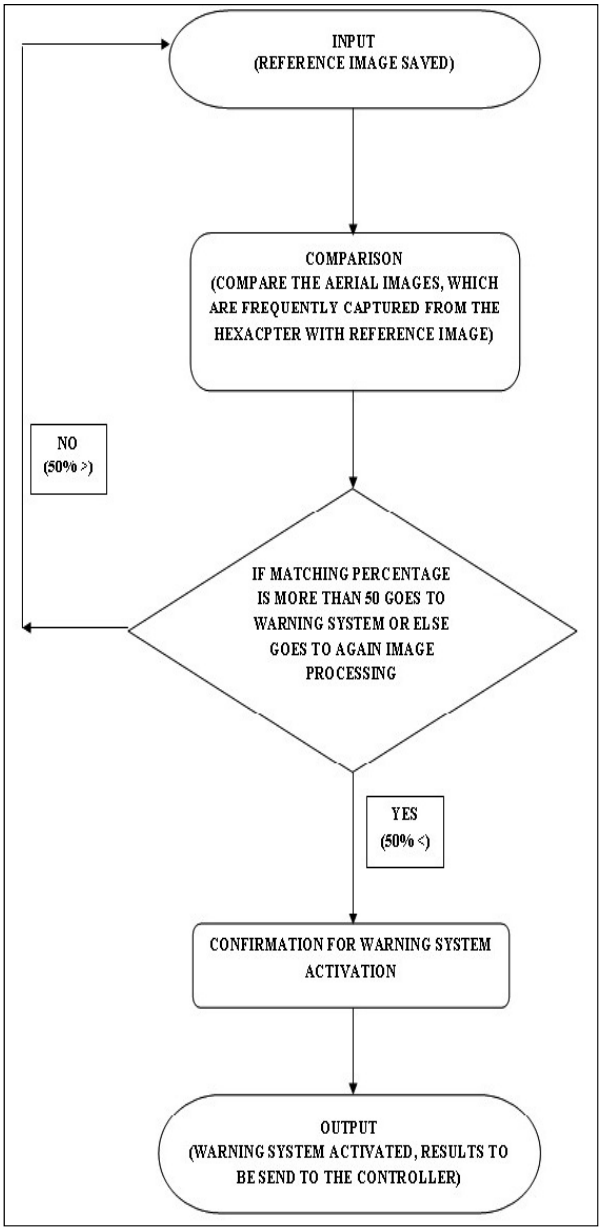

Figure-4. Flow chart of a detection algorithm.

Case 1: Image matching percentage for different angles

Figures 5, 6 show the reference image and aerial captured image during flight for image processing.

Figure-5. Hexacopter reference image for processing.

Figure-6. Aerial image.

Result file:

Figure-7. MATLAB result for amount of image matching.

Figure-7 shows simulation result of the image matching error percentage by MATLAB for case 1. The matching region in captured image compared with reference image is 100, because both the images are same for animal detection algorithm verification.

Case 2: Image matching percentage analysis for animal

Figures 8, 9 show the reference image and aerial image captured during flight. Both reference and aerial images are taken from internet for algorithm cross checking.

Figure-8. Reference animal image.

Figure-9. Aerial image.

Result file:

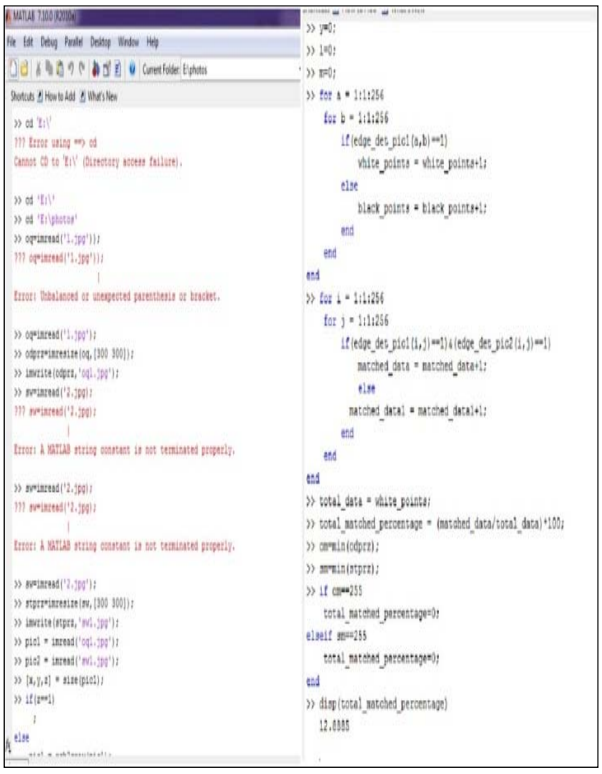

Figure-10. MATLAB result for animal image matching.

Figure-10 shows result of the image matching error percentage simulation by MATLAB for animal images. The matching region in captured image compare with reference image is 12.8085.

CONCLUSION AND FUTURE WORK

Hence the proposed Hexacopter is a better solution for animal poaching, animal - human interaction problem and animal counting's and also it has unique characters such as more comfortable flight, less vibration so it can able to reliable and capable to withstand any critical environment for a practical application such as animal detection, activation of warning system. With the help of six propellers hexacopter can able to track any moving animal as well as cover the whole predefined forest region. Image processing has been done for different cases by MATLAB for the alert activation purpose. The Remote Controlled hexacopter prototype has been carried out and the image processing results are plotted. The fully autonomous hexacopter and its real time simulation results are will be carried out.

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