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Design and Development of Autonomous UAV for Thermographic Surveillance

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Abstract: UAVs are being utilized to scout the area in conflict zones. To increase effectiveness, surveillance drones can be equipped with thermal imaging cameras. Using a thermal imaging camera, thermographic surveillance is accomplished. A UAV is created to fulfil the mission's criteria. A quadcopter is developed and evaluated, and the weight of the UAV is approximated. Arduino is used for data collecting and camera capture. An image capture is delivered to a web server. Utilizing image processing techniques like linear contrast adjustment and CLAHE, the image is further improved.

Keywords: Autonomous UAV; Thermographic surveillance; Thermal Imaging; Thermal Image Enhancement.

I. INTRODUCTION

UAV is an Unmanned Aerial Vehicle which is remotely controlled or autonomous, with payload or no load with no pilot onboard. In recent years UAVs are incorporated with many sensors such as lasers, infra-red and optical sensors to imitate the human eye. Thermographic surveillance uses a thermal imaging camera which converts heat emitted by animals to images. ESP 8266 Wi-Fi module is a microcontroller which can be programmed to the need of user. It also has a built in Wi-Fi module. ESP can also perform the functions of telemetry. Autonomous drones make use of GPS module to navigate to the location input given to the drone. Thus, eliminating need of pilot and maximizes the efficiency of response time. Thermal image is obtained from web server of ESP and enhanced in MATLAB using algorithms such as linear contrast adjustment, CLAHE.

II. LITERATURE SURVEY

The publications [1- 4] give an overview of the development of autonomous drones. The issues that need to be taken into account while constructing drones are being examined. It involves examining each and every operation's requirements, such as the minimal operational time, the needed range and endurance, and the ability to manoeuvre. A GPS module is used by an automated drone in [3] follows waypoints, which are programmed GPS sites.

The publications [4-7] describe the development of automated detection of live creatures using thermal cameras, which have a small on-board computer that can recognise an animal's heat signature from a set height.

The publications [8-10] describe a novel algorithm for analysing thermal pictures that is based on a few chosen automated quantitative automatic approaches. Additionally, this study demonstrates how to use MATLAB to obtain and analyse a thermal picture. The methods discussed in [10] are relatively simple to use and may dramatically alter photographs that are darker, sunnier, or have lower contrast. When image enhancement techniques are used, the quality of the resulting image is greatly improved, making it superior to the original image.

Utilizing computer vision to improve thermal images can fill in the gaps left by low quality thermal images produced from thermal image surveillance as thermal cameras deployed from quadcopters at specific heights will occasionally provide noisy and blurry images.

III. MATERIAL AND METHODS

Fabrication of UAV needs many electronics and a frame, thermal imaging needs a thermal camera, a tiny microcontroller for image acquisition and flight con-troller for drone and other basic electronics. These electronics are housed in quadcopter frame which is fabricated using different methods. The electronic components used are listed in Table 1.

The materials of the quadcopter should have high strength value whereas the weight of the structure should be as less as possible. PLA was chosen as the material for the quadcopter's arm since it can be 3D printed inexpensively and with acceptable strength. While fibre glass was chosen for the quadcopter's central hub because it is readily accessible and can be laser cut to the necessary model. Landing gear is made of carbon fibre rods since they are stronger and lighter.

TABLE 1. LIST OF ELECTRONICS USED

Sl no	Name of the Material
1	A2212 1400 BLDC motor
2	Simonk 30A ESC
3	Lemon 5000mah 3s 25/50c Battery
4	Ardupilot 2.8
5	Propeller 10*45
6	Nodemcu ESP 8266
7	MLX 90614 thermal imaging camera
8	Ublox Neo 7m Gps module
9	Power distribution board
10	Vibration pad

TABLE 2. MATERIAL PROPERTIES

Materials	Density (g/cm^3)	Ultimate Tensile Strength(MPa)	Ultimate Yield Strength(MPa)
PLA	1.25	32.93	26.082
Glass Fiber	1.44	$3.310*10^3$	$3.03*10^3$
Carbon fiber	1.9	$3.3*10^3$	$4.62*10^3$

1. *Design Requirements*

Quadcopter is designed using the selected materials and defining the requirements of mission. Following are the mission requirements and design parameters for conducting safe and successful missions.

a. Minimum Payload carrying capacity =85gms

b. Minimum Endurance = 10-12min

c. Minimum Design safety factor = 2

2. *Design Estimation*

In order to choose the components of the quadcopter that would best assist to overcome its weight, weight calculations and endurance calculations must be done.

2.1 Weight estimation

Estimation of weight of the drone is important, inorder determine the minimum thrust required to lift the drone. The weight can be spilt into drive, electronics, body and payload. The drive consists of motor, propeller, ESC and battery. The body and electronics consist of airframe, flight controller, GPS, power distribution board. The payload includes thermal module, camera controller.

TABLE 3. WEIGHT ESTIMATION

Parts	Weight(grams)
Airframe	200
Motor(x4)	280
Propeller(x4)	40
ESC(x4)	92
Battery	260
Flight Controller	30
GPS	30
Power Distribution Board	28
Payload	150
Total	1110

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2.2 Thrust Estimation

After calculating the weight based on the values obtained from the manufacturer details, the total weight including payload obtained was 1110 grams. For the drone to hover at 50% throttle, T/W ratio value should be 2. Therefore, $\boldsymbol{T_R = 2220gm}$. The minimum thrust required for hover at 50% throttle was 2220 grams. Adding 180 grams of extra thrust to the TR to give some extra headroom. The final thrust required summed up to 2400gms.

2.3 Endurance

Flight time can be calculated by putting battery capacity (5000mah), battery voltage (11.1v), and battery discharge 80%, P assumed to be 170w/kg, Weight (1.1kg) in the following relation and the time of flight equals to 14.24 mins.

$$Flight\ Time = Capacity \times \frac{Discharge}{\left(\frac{p}{v} \times Weight\right)} \times 60$$

3. Design

Every quadcopter or multirotor aircraft needs a frame to house all the other components. Dimensions of the avionics used on the frame were primarily considered while designing the air-frame. For the modelling of quadcopter airframe, CATIA software is used. The parts of the quadcopter were individually designed and assembled. An ISO view of quadcopter assembly is shown in Figure 1.

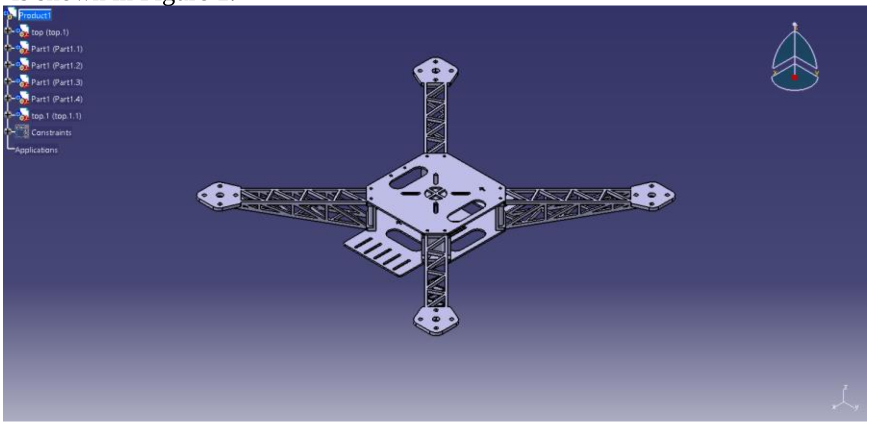

FIGURE 1. ISO VIEW OF QUADCOPTER ASSEMBLY

4. Analysis

Understanding how the structure responds to loads like thrust from the propulsion system is required for examination of the quadcopter model. Tetrahedral mesh with tiny element size is present in the mesh used for the structural analysis of the assembly. Since the motor is producing an 800 gm thrust force, the junction of the fixing arm and the central plate was fixed for analysis, and a force of 7.84 N was applied to the free end of the arm.

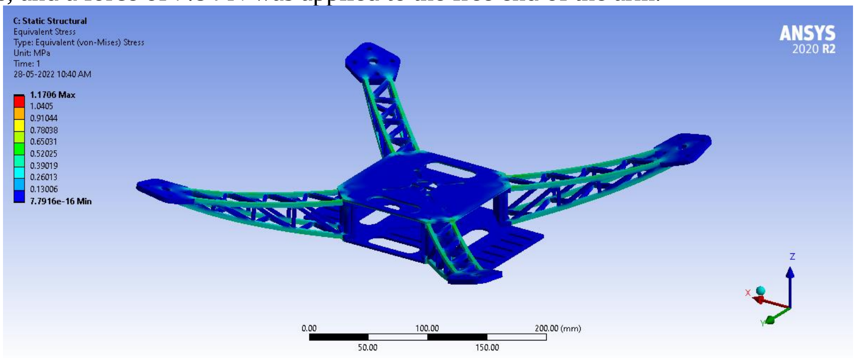

FIGURE 2. STRESS DISTRIBUTION OF QUADCOPTER ASSEMBLY

Static structural analysis of the Quadcopter Assembly are analyzed for stress distribution. Maximum stress developed for the whole assembly was 1.17 MPa.

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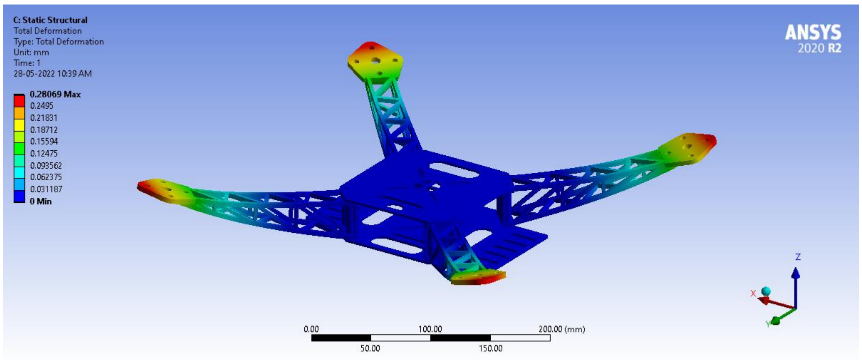

FIGURE 3. DEFORMATION OF QUADCOPTER ASSEMBLY

The static structural analysis of Quadcopter Assembly produced the maximum deformation of 0.28 mm .Figure 4 shows the quadcopter's built-in frame and the connections between its electrical parts.

FIGURE 1. QUADCOPTER FINAL ASSEMBLY

5. *Data acquisition and image processing*

The http webserver protocol is used to gather data from the ESP 8266 and Thermal Camera MLX 90614 devices. Each picture is retrieved by the client making a http request to the server, which then shows the image. The recorded image will be saved using the Little FS system. To process http requests, the programme makes use of async webserver and async TCP libraries. Image enhancement, both in terms of colour and contrast is added to get photographs for better discrimination between the surroundings and humans or animals.

4. *Results and Discussions*

Solutions are acquired by a number of computations, such as the quadcopter's weight, which is derived by incorporating material attributes into the analysis's data. Utilizing the analysis's maximum stress result, the factor of safety is computed. Data acquisition over a web server using arduino software and MATLAB image processing.
Table 4. Shows the material properties of arm and plate, using these properties weight of frame was obtained which is 200 gm.

TABLE 4. ANSYS SOLUTIONS

Part	Max Stress (MPa)	Material Ultimate Strength (MPa)	Maximum Deformation (mm)
Assembly	1.17	(arm) 32.93, (plates) $3.310*10^3$	0.28

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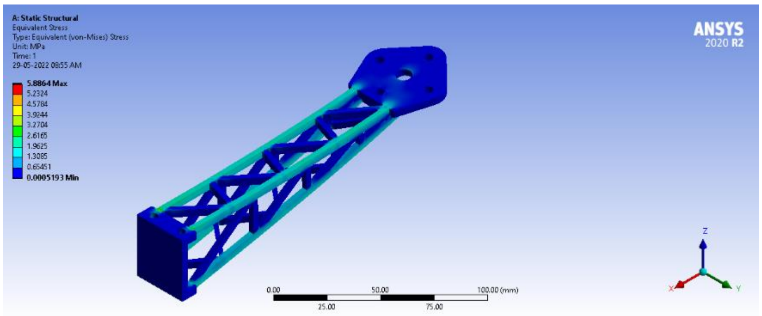

FIGURE 2. STRESS ANALYSIS OF QUADCOPTER ARM

Figure 5 shows the structural analysis of quadcopter arm. Maximum stress developed in the arm was found to be 5.8864 MPa. Using ultimate tensile strength of PLA material (32.938MPa) and working stress of the arm (5.8864MPa), the Factor of Safety (5.59) was calculated.

The website will display the thermal camera's captured image, from which we may store it in the input folder for image improvement. From there, the image will be further enhanced using MATLAB code. Figure 6 shows the improved color and contrast images.

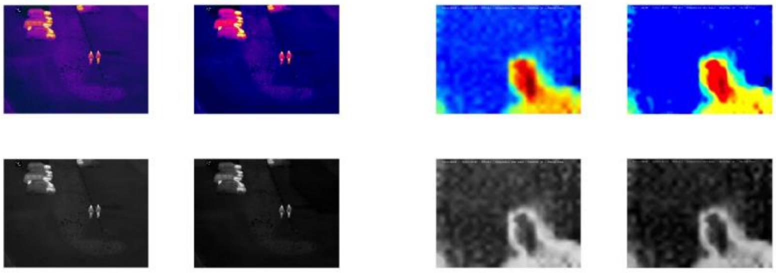
FIGURE 6. ENHANCED IMAGE (A) AND (B)

Results and solutions from Ansys validate the safety of the quadcopter frame, which has a FOS value of 5.59 and can bear all forces generated by installed equipment. A model with a factor of safety of 5.59 will be error-free and defect-free. The set interval function in the data acquisition system is used to periodically get thermal camera pictures for presentation in the web server. The operating range of ESP, which is de-pendent on an internet connection, is constrained when used for surveillance.

Thermal image enhancement using MATLAB code can improve the low-quality pho-tos obtained by thermal camera MLX and aid in obtaining better-quality images from which further image processing can be carried out to more accurately discriminate between alive and non-living items.

IV. CONCLUSION

UAVs are becoming popular for use in deliveries and the military, among other things. Our work focuses on creating a UAV with an autonomous flight control system and a thermal imaging camera capable of capturing data remotely to aid in times of natural disasters like earthquakes, floods, and slides. UAVs may autonomously explore the area of interest and broadcast the imagery to ground stations to give relief to survivors, assess damage, and find survivors. Search and rescue operations for individuals can be enhanced by the employment of UAVs with increased telemetry range, capabilities, and thermal camera quality.

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