Design and Development of a 3D-Printed Quadcopter Drone for Educational Autonomous Flight and Research Applications

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***Abstract*— This paper presents the design, fabrication, and development of a 450-mm educational quadcopter, constructed using 3D printing (FDM) and safe, low-voltage electronics. Designed as a first-year engineering project, the platform demonstrates fundamental principles of unmanned aerial systems (UAS), including lightweight structural design, propulsion control, and sensor fusion. The drone features a 450mm frame, brushless propulsion system, onboard APM 2.8 flight controller, and a sensor suite comprising light dependent resistor, ultrasonic sensor, temperature, and gas. A modular motor arm layout, electronics bay, and quick-release battery tray allow easy assembly and repair—critical for undergraduate learning. Experiments show stable indoor and outdoor hovering, and waypoint navigation in controlled environments. The system provides a safe, cost-effective platform for teaching UAV design, and mechatronic integration.**

***Index* — quadcopter drone, 3d printing, brushless propulsion, sensor fusion**

I. INTRODUCTION

Unmanned aerial vehicles (UAVs) have become integral to modern applications ranging from agriculture and robotics research. However, commercial drones often lack transparency in hardware, software, and control architecture, limiting their use in structured learning environments. To enable hands-on, multidisciplinary learning, this project presents a scaled, educational quadcopter platform designed for first-year BTech AI and Robotics students under the flexibility encouraged by NEP 2020. The model focuses on safe electronics (<16 V), 3D-printed modularity, and open-source control, allowing students to explore aerodynamics, propulsion, AI navigation, and real-time control. This paper details the design methodology, structural fabrication, embedded control development, experimentation, and educational impact of the 1 m quadcopter.

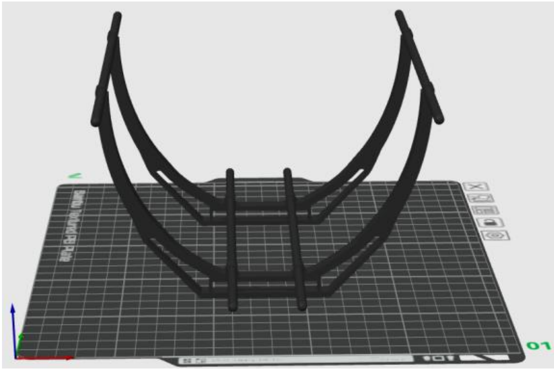

Figure 1 - 3-D CAD Model of the Landing Gear used in the 450 mm Quadcopter

Assembled Prototype Model of the 450 mm Quadcopter

A. Figures and Tables

The quadcopter is a UAV with a total footprint measuring approximately 450-milimeters in length and 0.8-meter in width and 0.4-meter in height. The entire system weights approximately 1.2~1.5 KG. The robot is powered by a 5200 mAH Li-po battery which is used for the sensor module and the actuators. The combined power system is sufficient to deliver energy for 45 to 60 minutes depending on usage. ESP-32 VROOM is used as the microcontroller for the initial prototype. A PDB board is used to deliver power and control all 4 brushless motors. The quadcopters body consists of 2 major parts – The frame and landing gear. Motion of the quadcopter works on 3 rotatory axes:

- Horizontal (yaw)
- Vertical(pitch)
- Forward(pitch)

This configuration is similar to the principles of human leg and offers a large working envelope while maintaining low center of gravity.

The quadcopter frame was a standard 450 mm frame and the landing gear was designed using Autodesk Fusion360, allowing advanced parametric modelling and software-based simulations.

Parameter	Value
Nozzle diameter	0.2mm
Layer Height	0.2mm
Infill	20~40% (Gyroid Pattern)
Material	PETG
Print Time	~9 Hours 30 Minutes
Filament Used	125g
Assembly	M2 Screws and zip ties
Component	Function
ESP-32 VROOM	Central controller
MQ-135	GAS Sensor to detect AQI and Gas Composition
KY-015	Temperature/Humidity sensor
HC-SR04	Obstacle sensing(front)
APM 2.8	Flight controller to calibrate the quadcopter
Battery	12V 5200mAh
Motors	A2212 1000 KV Motors

Future development will focus on:

1. Integration of Li-DAR and ESP-CAM for autonomous terrain mapping.
2. Implementing YOLOv3 machine learning algorithm to use sensor data to obtain information with human intervention.
3. Upgrading motors for more stability and torque.
4. Developing a modular sensor pod for environmental mapping.

B. Abbreviations and Acronyms

ESP → Espressif Systems Platform
PID → Proportional–Integral–Derivative
IMU → Inertial Measurement Unit
LiDAR → Light Detection And Ranging
UAV → Unmanned Aerial Vehicle
UAS → Unmanned Aircraft System
FDM → Fused Deposition Modeling
YOLOv3 → You Only Look Once – Version 3

C. Equations

$$T = k_T \times \omega^2 \qquad (1)$$

Where T = thrust (N), k_T = thrust coefficient, ω = motor angular velocity (rad/s)

$$F_{total} = k_T(\omega_1^2 + \omega_2^2 + \omega_3^2 + \omega_4^2) \qquad (2)$$

$$u(t) = K_p \cdot e(t) + K_i \cdot \int e(t)dt + K_d \cdot (de(t)/dt) \qquad (3)$$

where u(t) = Control signal, e(t) = Error signal, K_p = Proportional gain, K_i = Integral gain , K_x = Derivative gain

$$F_{total} = m \cdot g \qquad (4)$$

where M = mass of drone and g = gravity

$$P = V \times I \qquad (5)$$

where P = power, V= voltage, I = Current

$$t_{flight} = C_{battery} / I_{avg} \qquad (6)$$

where t_{sli}^{ghT} = flight duration , C = Battery capacity, I_{av}= Average current draw

$$\tau = r \times F \qquad (7)$$

where τ = Torque, r = Moment, F = Thrust force of the respective motor (N)

$$TWR = F_{total} / (m \cdot g) \qquad (8)$$

where TWR = Thrust-to-Weight Ratio , F_{total} = Combined thrust of all four motors, m = mass, g = gravity

VII. CONCLUSION

A 450 mm quadcopter platform built using an ESP-based controller (e.g., ESP32-WROOM), PID control, and onboard sensing through an IMU demonstrates a stable and responsive aerial system suitable for basic autonomy and navigation tasks. The integration of feedback control ensures precise attitude stabilization, while the sensor suite enables reliable orientation estimation and obstacle awareness. Combined with efficient propulsion and structural design, the system achieves a balanced trade-off between payload capacity, flight time, and maneuverability. Overall, this configuration provides a robust foundation for UAV applications such as surveillance, mapping, and robotics.

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