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Design And Fabrication Of Fully Functional Drone Using 3d Printing Technology

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Abstract : Drones, also known as Unmanned Aerial Vehicles (UAVs), have gained significant importance in various industries, including surveillance, agriculture, aerial photography, logistics, and disaster management. With the advancement of 3D printing technology, drone manufacturing has become more cost-effective, customizable, and accessible. Traditional drone frames are often made from carbon fiber or aluminum, which can be expensive and complex to manufacture. 3D printing offers an innovative solution by enabling lightweight, durable, and highly customizable drone designs at a lower cost.

This project aims to design and manufacture a drone body using 3D printing technology. The design process involves selecting suitable 3D printing materials, optimizing structural integrity, and integrating necessary components such as motors, battery, flight controller, GPS, and camera.

By leveraging 3D printing technology, this project demonstrates an innovative approach to drone design, making UAVs more accessible for various applications. The findings from this research can contribute to the development of cost-effective, lightweight, and portable drones, which are essential for modern aerial operations.

I. INTRODUCTION

Project Background

The rapid advancement of drone technology has opened up a wide range of applications across various industries, including aerial photography, agriculture, surveillance, logistics, and disaster management. With improvements in miniaturization, battery efficiency, and flight control systems, drones have become increasingly accessible for both hobbyists and professionals.

This project focuses on the design and development of a custom-built quadcopter drone, tailored for cinematic and general-purpose aerial applications. The aim is to create a cost-effective, stable, and lightweight drone capable of lifting a payload of up to 1.5 kg, including a camera and supporting electronics. The frame is 3D-printed to minimize weight and cost, and essential components such as motors, ESCs, GPS, video transmission systems, and sensors are carefully selected within a limited budget.

The project also provides an opportunity to apply principles of mechanical engineering, electronics, and programming in a practical, interdisciplinary environment. The goal is not only to build a functional drone but also to understand the integration of mechanical structure, power systems, flight control, and autonomous features like GPS-based navigation and follow-me functionality.

Through this project, we aim to enhance our technical skills and contribute to the growing body of knowledge surrounding unmanned aerial vehicles (UAVs), while exploring the potential for future applications in both commercial and humanitarian fields .

Problem Statement

Despite the availability of commercial drones, many are expensive, proprietary, and not easily modifiable. Educational institutions and research enthusiasts often face budget constraints that limit access to these systems. Moreover, commercial drones typically do not allow easy replacement of parts or customization for specific research purposes.

In addition to educational barriers, industries and small businesses face challenges in adapting drone technology to niche applications due to high costs and limited flexibility. Applications such as precision agriculture, real-time monitoring in construction, and localized logistics require platforms that can be tailored to specific needs without incurring excessive costs. Furthermore, emergency services in rural or resource-limited regions may benefit from low-cost drones for search and rescue, damage assessment, and communication relays.

There is a growing need for a low-cost, open-source, and easily repairable drone platform that can serve educational, experimental, and light-duty application needs. This project addresses the following key problems:

- Lack of budget-friendly drone platforms for learning and experimentation.
- Limited understanding of drone design and integration among students and professionals.
- High maintenance cost and complexity of commercial drones.
- Inaccessibility of customized drone solutions for small-scale industries and local service providers.
- Need for modular systems that can be adapted for various research and practical objectives.

Objectives

The primary objectives of this drone project are:

1. To design and 3D print a lightweight quadcopter frame suitable for educational and experimental use.
2. To select and integrate compatible off-the-shelf components including motors, ESCs, GPS, flight controller, and battery.
3. To configure and calibrate the flight controller using open-source software (e.g., Mission Planner).
4. To perform test flights, assess flight stability, and optimize performance through PID tuning and weight distribution.
5. To provide a modular drone platform that can be easily upgraded with additional features such as FPV, obstacle avoidance, and autonomous navigation.

Scope Of The Project

This project focuses on the mechanical design, electrical integration, and functional testing of a quadcopter drone within a fixed budget. The scope includes:

- 3D design and fabrication of the drone frame.
- Selection and integration of all required electronic components.
- Power system planning and management.
- Software configuration using open-source tools.
- Testing and calibration of drone subsystems.
- Basic performance evaluation under payload conditions.

The project does not cover long-range communication systems, advanced AI-based tracking, or commercial-grade payload systems. However, the designed platform allows future expansion in these areas.

Applications

The successful implementation of this drone project opens doors to multiple practical applications:

1. Aerial Photography and Videography: The drone can be equipped with a camera module for capturing aerial footage, useful in cinematography, journalism, and event coverage.
2. Educational and Research Tool: As an affordable and modifiable platform, the drone serves as an excellent tool for learning embedded systems, aerodynamics, and control systems in engineering education.
3. Agricultural Monitoring: With the integration of multispectral or thermal cameras, the drone can help monitor crop health, irrigation coverage, and pest activity.
4. Surveillance and Security: In areas requiring real-time monitoring such as campus security or traffic control, the drone can be adapted for short-range surveillance tasks.
5. Disaster Management: During emergencies like floods or earthquakes, drones can be deployed to assess affected areas, deliver small payloads, or locate survivors.

These applications highlight the growing importance of UAVs in modern society and validate the relevance of this project in both academic and practical domains.

II. Literature Review

Introduction

The literature review aims to provide a comprehensive overview of existing research, developments, and innovations related to drone technology, particularly quadcopters. This chapter analyses prior work in drone design, flight control systems, component integration, 3D printing applications in UAVs, and relevant case studies to establish a foundation for the current project.

Historical Background And Evolution Of Drones

Unmanned Aerial Vehicles (UAVs) have been in development since the early 20th century, originally serving military purposes for reconnaissance and target practice. With technological advances in electronics, materials, and software, UAVs have evolved into sophisticated, multi-purpose tools used in both commercial and non-commercial domains (Austin, 2010).

In recent years, quadcopters have gained popularity due to their simpler mechanical design compared to fixed-wing aircraft and helicopters. Their vertical take-off and landing capabilities, combined with precise manoeuvrability, have made them a preferred choice for research, hobby, and commercial applications (Gonzalez et al., 2019).

Review Of Flight Control Systems

Modern quadcopters rely on flight controllers to manage their stability and orientation. Open-source flight controllers such as APM, Pixhawk, and SpeedyBee F405 V3 are widely used for their affordability and flexibility. Literature suggests that PID control is the most common technique used to stabilize quadcopter flight, although more advanced methods like fuzzy logic and neural networks have been proposed for improved performance (Bouabdallah et al., 2004).

Kalman filters and sensor fusion techniques using gyroscopes, accelerometers, magnetometers, and GPS modules are integral for position estimation and navigation. Studies show that proper calibration and tuning of sensors significantly enhance flight stability and response (Kendoul, 2012).

Calculation

By Pinch test, the manufacturer will conduct this test on the many propeller and will give you the thrust on each propeller.

The Main parameter affecting the thrust force:

1- 3 Parameter in the propeller (Pitch, Diameter, material)

2- 2- One Parameter in the Motor (RPM)

3- 3- One parameter in the atmosphere. (Air)

Lets, start with

RPM:

RPM will be function in two thighs

A -KV

B -volt in the battery.

This will let me know the RPM for the motor. For example, 600 KV motor powered by 11.1, the max RPM= 11.1 x 600= 6,660 RPM.

Propeller

The size of propeller will contain two number example 10 x 4.5 inch that mean 10 is diameter of propeller and 4.5 is the pitch. In the theory the diameter is related to Thrust force, if the diameter increased the Thrust force will increase. Also, the pitch related to the speed of the drone, if we increased the pitch the speed will be increased but the problem if we increase the pitch the turbulent will occurred.

Flight time

Before procured any battery, you need to know

1- mAh
2- number of C which is the maximum discharge rate can produce by battery.
3- The Volt, we should know this number to multiply with KV to get the Max RPM like example above.

How we can select the battery?

The main information that you need to know to select the write battery:

1- Lipo Cells: example in the battery we have 3s that meat 1 Cell = 3.7V so, 3 Cells= 3.7x3=11.1V. that mean you can`t apply more that 11.1 volt in this battery.
2- Max Current: X Number of Motor = Max Ampere required (Battery must deliver this Ampere which is mentioned in the data specification)

Integration Of 3d Printing In Drone Design

3D printing has revolutionized drone fabrication by enabling custom frame design and rapid prototyping. Researchers have explored the use of materials such as PLA, ABS, and nylon composites for building lightweight and durable frames. Literature emphasizes the role of frame geometry in influencing aerodynamic performance and load distribution (Mohammed et al., 2018).

Several studies highlight the benefits of modular 3D-printed designs, including easier maintenance, lower replacement costs, and the ability to experiment with various configurations for academic purposes (Singh & Singh, 2020).

Battery And Power Systems

Battery selection is critical in UAV performance. Lithium Polymer (LiPo) batteries are preferred for their high energy density and discharge rates. Research indicates that optimal battery capacity and discharge rate must be matched with motor specifications to achieve desired flight time and performance (Zhang et al., 2016).

Thermal management and power distribution are also crucial for drone longevity and safety. Academic studies recommend the use of Power Distribution Boards (PDBs) and Electronic Speed Controllers (ESCs) with current protection features (Patel et al., 2019).

Sensor Technologies And Communication Modules

Literature reveals that the use of GPS modules (e.g., uBlox NEO-M8N) enhances autonomous flight capabilities, especially when combined with barometric sensors and magnetometers. Communication modules such as 5.8 GHz video transmitters (VTX) and telemetry radios are essential for real-time data transfer and FPV (First Person View) operation (Gupte et al., 2012).

Emerging technologies include the integration of computer vision and AI-based sensors for obstacle avoidance and object tracking, indicating the direction for future drone advancements (Floreano & Wood, 2015).

Case Studies And Comparative Analysis

Various academic projects have documented the development of quadcopters for diverse applications such as agriculture, mapping, and surveillance. These studies emphasize the need for cost-effective, modular, and user-friendly drone systems for research and field use (Dabove et al., 2020).

For instance, a project by Stanford University used a 3D-printed frame and Pixhawk controller to develop an autonomous agricultural drone, reporting significant cost savings and flexibility in design. Another study focused on indoor drone navigation using optical flow sensors and showed promising results for confined space operations (Raimondi et al., 2019).

Summary

The reviewed literature highlights the critical role of open-source platforms, modular construction, and 3D printing in promoting advancements in drone technology. It also sheds light on challenges such as efficient power management, precise sensor calibration, and adapting to various environmental conditions. This project leverages these insights to develop a customizable and cost-effective quadcopter suitable for both academic exploration and practical use.

III. SYSTEM DESIGN AND ARCHITECTURE

Introduction

This chapter details the overall system design and architecture of the drone project, focusing on the mechanical, electrical, and software components that form the complete UAV system. The integration of these subsystems ensures optimal performance, stability, and functionality during drone operation.

System Overview

The quadcopter system comprises the following primary subsystems:

- Flight Controller (SpeedyBee F405 V3)
- Brushless DC Motors (Emax MT2213 935KV)
- Electronic Speed Controllers (50A ESCs)
- Lithium Polymer Battery (Bonka 4200mAh 4S 14.8V 35C)
- 3D Printed Frame
- GPS Module (uBlox NEO-M8N)
- Compact FPV Camera with Integrated 5.8 GHz VTX Module
- Sensors (Gyroscope, Accelerometer, Barometer, Magnetometer)
- Transmitter and Receiver

Schematic Block Diagram

The schematic block diagram below (Figure 3.1) illustrates the core components and how they interact within the drone's electrical and control system. It serves as a blueprint for understanding power flow, signal communication, and overall integration of the subsystems provides a high-level representation of the drone’s system architecture:

Figure 1 : Schematic Block Diagram

Mechanical Design

The drone frame is 3D printed using PLA, with dimensions of 325 mm × 308 mm and a weight of 350 grams. The frame supports the motor mounts, battery holder, and landing gear. The design was optimized for strength-to-weight ratio and modularity.

Key mechanical considerations include:

- Center of gravity alignment for stability
- Vibration isolation for the flight controller
- Proper airflow for motor cooling

Theory and Theoretical Calculations.

The calculation of the Quadcopter based on seven factors which given as:

1- Force and moments

$F_i = K_f \times \omega_i^2$

$M_i = K_m \times \omega_i^2$

$M_y = (F_1 - F_2) \times L$

$M_x = (F_3 - F_4) \times L$

Weight= mg

2- Newton’s second law of motion.

* for linear motion:

Force = mass x linear acceleration.

* for rotational motion:

Torque = Inertia x angular acceleration

3- Hover condition.

$mg = F_1 + F_2 + F_3 + F_4$

All Moments= 0

4- Rise motion.

$mg < F_1 + F_2 + F_3 + F_4$

All Moments= 0

5- Drop motion.

$mg > F_1 + F_2 + F_3 + F_4$

All Moments= 0

6- Yaw motion.

$mg = F_1 + F_2 + F_3 + F_4$

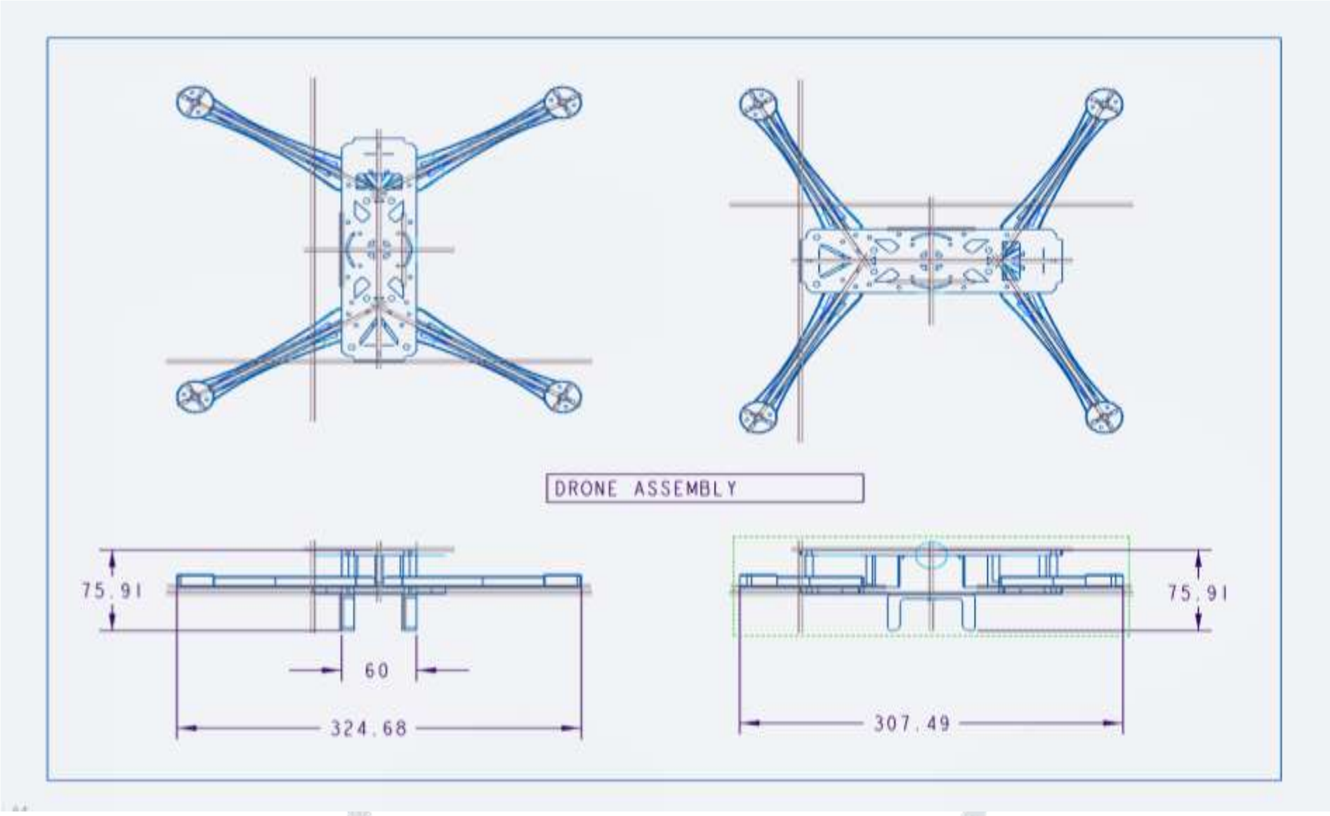
All Moments $\neq 0$

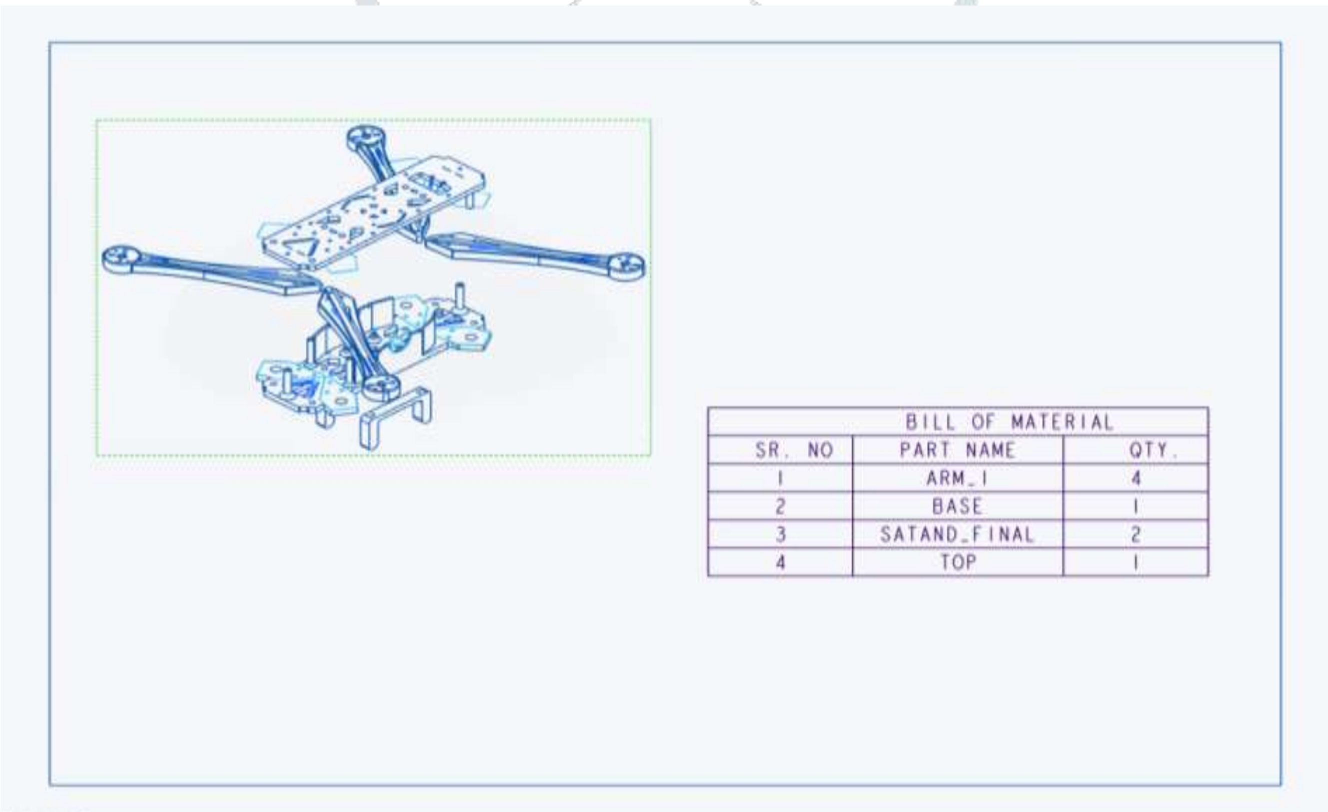
7- Pitch and Roll motion.

$mg < F_1 + F_2 + F_3 + F_4$

All Moments $\neq 0$

3.4.2 Working Drawing





Modelling of a Quadcopter dynamics.

This section presents the basic Quadcopter dynamics. The basic idea of the movement of the Quadcopter is shown in the following figure. It can be seen from the figure that the Quadcopter is simple in mechanical design compared to helicopters. Movement in horizontal frame is achieved by tilting the platform whereas vertical movement is achieved by changing the total thrust of the motors. But Quadcopter arise certain difficulties with the control design.

Figure 11

A coordinate frame of the Quadcopter is shown in the figure below.

The Quadcopter is designed on the following assumptions:

- The structure is supposed to be rigid.

- The Centre of Gravity and the body fixed frame origin are assumed to coincide.
- Thrust and drag are proportional to the square of the propeller's speed.
- The propellers are supposed to be rigid.
- The structure is supposed to be axis symmetrical
- Rotation matrix defined to transform the coordinates from Body to Earth co-ordinates using Euler angles φ- roll angle, θ- pitch angle, ψ- yaw angle.
- About by φ, by θ and by ψ

Special attention should be given in the difference between the body rate measured p, q, r in Body Fixed Frame and the Tait-Bryan angle rates expressed in Earth Fixed Frame. The transformation matrix from [φ θ ψ]T to [p q r]T is given by:

Moreover, the rotation matrix of the Quadcopter's body must also be compensated during position control. The compensation is achieved using the transpose of the rotation matrix.

Electrical Architecture

The power distribution system is managed directly by the SpeedyBee F405 V3 flight controller, which includes built-in power distribution capabilities, making an external Power Distribution Board (PDB) unnecessary in this setup. The system includes:

- A Power Distribution Board (PDB) for routing power from the battery to the ESCs
- ESCs connected to each of the four motors
- Voltage regulators and filters to supply stable power to the flight controller and peripherals

Safety features include:

- Fused connections
- Proper grounding
- Secure connectors to prevent mid-air disconnections

Figure 13 : SpeedyBee F405 V3 flight controller with ESC

Software Components

The drone utilizes open-source firmware (INAV or Betaflight) on the SpeedyBee F405 V3 flight controller. Configuration is performed via the SpeedyBee app or Betaflight Configurator on PC.

Software functionalities include:

- PID tuning
- Sensor calibration
- Failsafe settings
- GPS waypoint navigation

Communication Architecture

The communication system is composed of:

- A 2.4 GHz transmitter-receiver pair for manual control
- A compact drone camera with integrated 5.8 GHz video transmission module for real-time FPV feed
- Telemetry modules for data transmission to ground control

This ensures reliable data and control signal exchange between the drone and the user.

Integration And Testing

System integration was carried out in phases:

1. Mechanical assembly
2. Electrical wiring and power tests
3. Software setup and calibration
4. Dry run and tethered testing
5. Final flight tests

Each phase included verification steps to ensure performance and safety.

Summary

This chapter outlined the structural, electrical, and communication architecture of the quadcopter. Emphasis was placed on subsystem integration to ensure efficiency, modularity, and ease of maintenance. The detailed design process forms the basis for achieving a stable and responsive UAV platform.

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