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DESIGN AND DEVELOPMENT OF A GROUND-BASED TEST BED FOR PERFORMANCE EVALUATION OF VTOL UAVS

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INTRODUCTION & AIM

INTRODUCTION:

- Unmanned Aerial Vehicles (UAVs) play a vital role in modern aerospace applications such as surveillance, monitoring, mapping, and defense. Vertical Take-Off and Landing (VTOL) UAVs combine hovering capability with efficient forward flight, making performance evaluation essential during development.
  This project presents the design and fabrication of a ground-based test bed to safely evaluate
- UAV control surface performance (aileron, elevator, and rudder). The system simulates roll, pitch, and yaw motions under controlled conditions while collecting real-time sensor data for analysis and control validation. The setup reduces testing risks, lowers costs, and improves accuracy during early UAV development stages.

AIM:

- To design a ground-based test bed for VTOL UAV
- To enable safe testing of roll, pitch, and yaw motion
- To reduce risk and cost of flight testing
- To integrate sensors for real-time data acquisition
- To analyze and validate UAV performance data
- To develop a reliable and repeatable testing system

METHOD

Requirement Analysis
- Identified need for safe, low-cost UAV testing without actual flight
- Defined evaluation parameters: roll, pitch, yaw motion

Design
- Developed ground-based test bed concept with controlled motion ,Created detailed CAD model using CATIA

Fabrication
- Built aluminium frame structure for strength and stability
- Implemented joint mechanism to allow controlled movement

Integration
- Integrated ESP32 and IMU sensor (BNO055)
- Enabled real-time data acquisition and communication

Testing
- Conducted experiments to observe roll, pitch, yaw behavior
- Collected motion data under controlled conditions

Validation
- Compared experimental data with software/simulation outputs
- Verified accuracy and reliability of the system

RESULTS & DISCUSSION

Results Achieved

- Obtained accurate and consistent roll, pitch, and yaw values, validating sensor performance.
- Experimental results closely matched simulation and software outputs, confirming system reliability.
- Generated reliable datasets (attitude, acceleration, dynamic response) for further UAV analysis.
- Successfully validated structural stability and functionality of the test bed through experiments

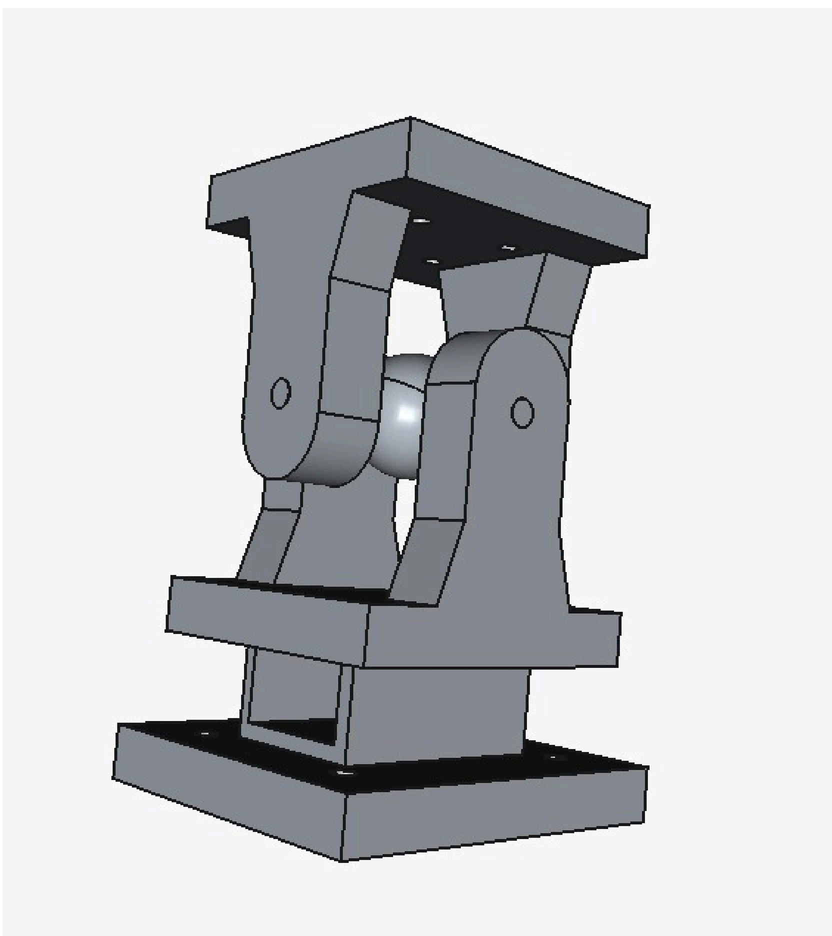

Fig. 1. CAD Model of Universal Joint

Fig. 2. Final Assembly of Testbed with Drone

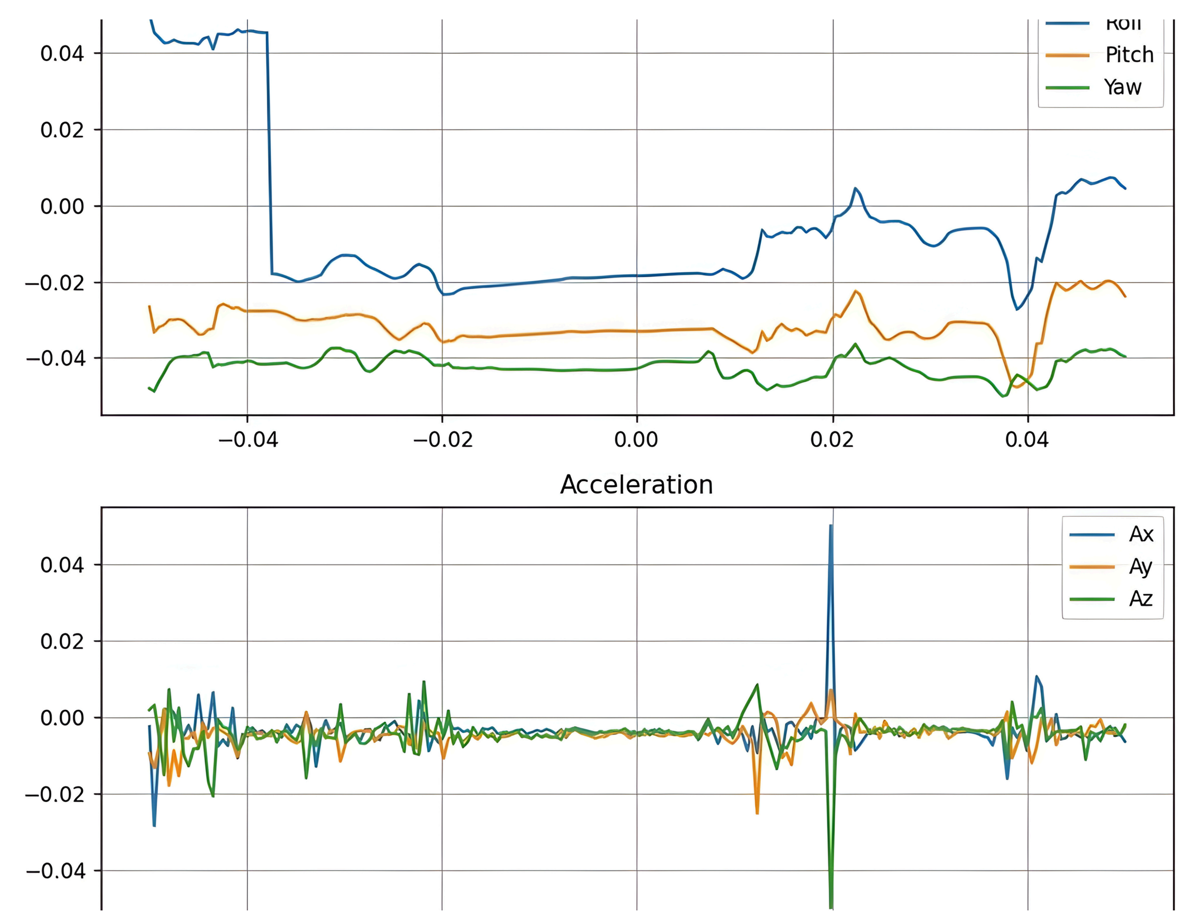

Fig. 3. Orientation & Acceleration ouputs from IMU Sensor

Fig. 4. 3D Printed Universal Joint with Flange bearing

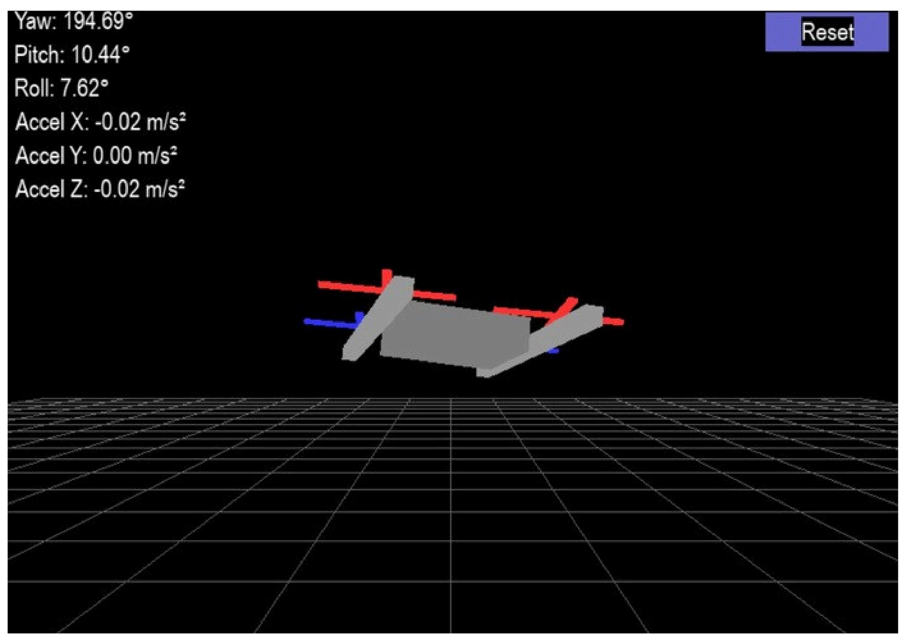

Fig. 5. Yaw visualization through VS Code

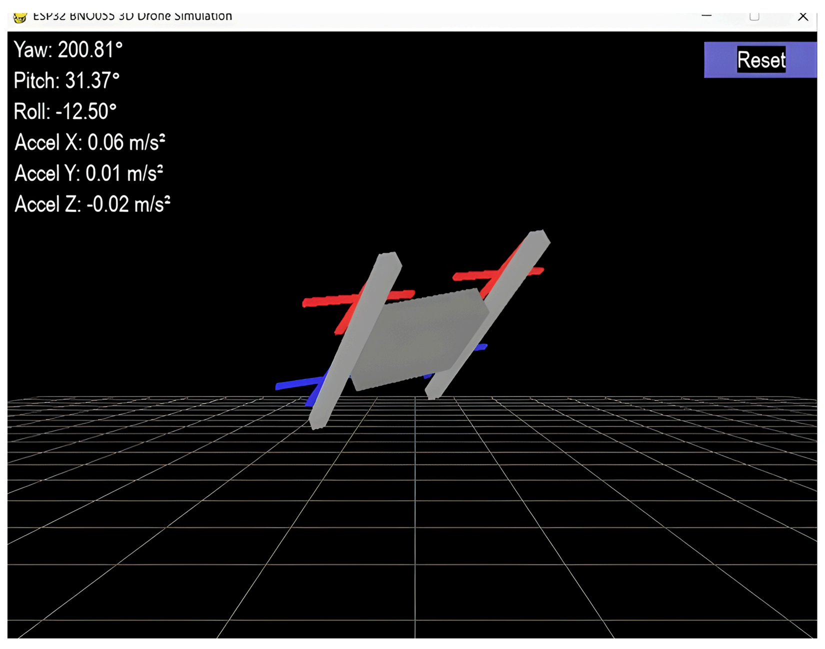

Fig. 6. Pitch visualization through VS Code

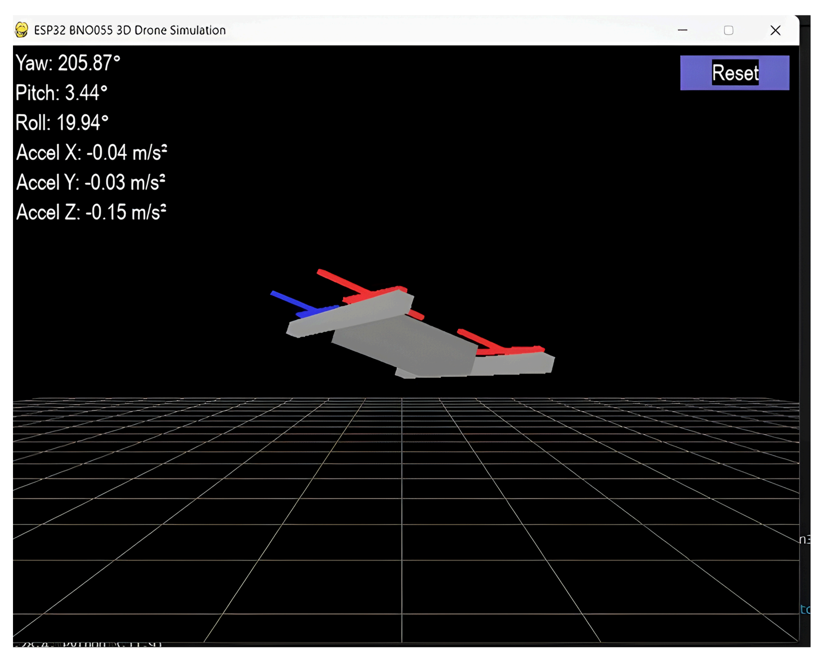

Fig. 7. Roll visualization through VS Code

CONCLUSIONS

- The UAV ground-based test rigprovides asafeand effective platform for analyzing UAV flight dynamics in controlled laboratory conditions.
- The system integrates a rigid aluminium structure, universal joint mechanism, IMU-based sensing, and real-time data acquisition.
- This integrated design enables accurate measurement of UAV attitude and motion behavior.
- Experimental validation confirmed the structural stability of the test rig.
- The system demonstrated reliable functional performance during testing.
- The setup proved to be consistent and dependable for repeated experiments.
- The collected datasets and simulation results offer valuable insights into UAV stability and control response.

FUTURE WORK/ REFERENCES/ACKNOWLEDGMENT

- **PID Tuning Integration:** Implementation of PID-based closed-loop control to improve stability, response accuracy, and control precision of the VTOL UAV during testing.
- **Incorporation of Linear Rails:** Adding precision linear rails to enable controlled translational motion, supporting dynamic aerodynamic testing and improved simulation of real-flight conditions.
- **Expansion to Five Degrees of Freedom (5-DOF)** :Upgrading the test bed to allow pitch, roll, yaw, heave, and sway motions for a more comprehensive evaluation of UAV stability and performance.