

DESIGNING AN AUTONOMOUS DRONE FOR FUTURE INDOOR PRECISION NAVIGATION

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PROBLEM

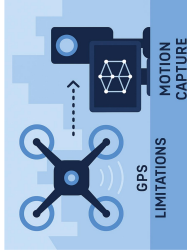
- Drone navigation is typically dependent on GPS, which is not available indoors, making it difficult to achieve precise autonomous control. This limits applications in research, warehouse automation, and robotics education.



- To address this, our project focuses on using motion capture systems for real-time position tracking, enabling GPS-independent indoor navigation. The goal is to create a reliable, reusable platform for future control system testing and autonomous flight research.

INTRODUCTION

- Autonomous drones have the potential to revolutionize logistics, surveillance, research, and indoor mapping. However, the lack of reliable indoor positioning remains a major challenge for deploying drones in GPS-denied environments such as warehouses, laboratories, and disaster sites. Traditional GPS systems cannot penetrate buildings, making it difficult for drones to maintain accurate localization and stability indoors.
- This project addresses that gap by developing a foundational drone platform designed for indoor autonomous navigation using motion capture technology.



- By leveraging the OptiTrack system for real-time tracking, along with PX4 firmware and MAVLink-based communication, this project aims to enable precise closed-loop PID control and future autonomous behaviors like waypoint following, hovering, and path planning without relying on GPS.

ENGINEERING OBJECTIVES



GOAL

To develop and validate a drone platform capable of stable indoor flight using motion capture data for future autonomous control research.

CRITERIA

The drone must be able to safely arm, take off, and maintain stable motion while performing precise indoor navigation tasks, including position tracking and demonstrate sufficient PID tuning to support future autonomous control using MAVLink communication.

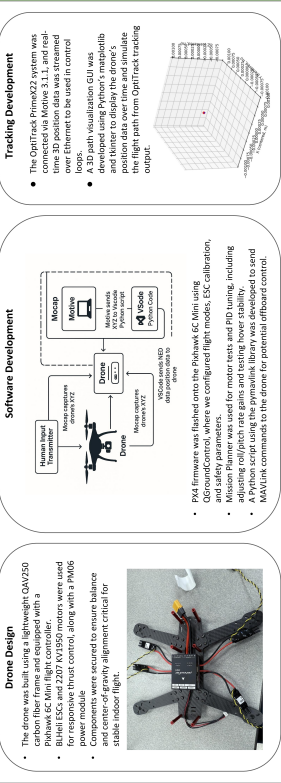
ENGINEERING METHODS AND DESIGN ADVANCEMENT

ENGINEERING COMPONENTS

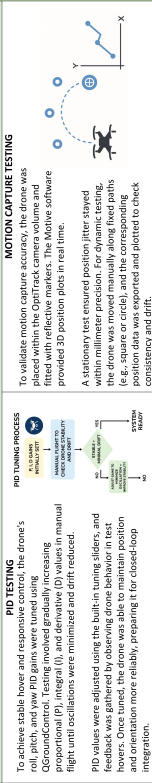
We selected cost-effective yet reliable components compatible with PX4 firmware and motion capture systems, ensuring a stable test platform for future autonomous control development.



DESIGN DEVELOPMENT

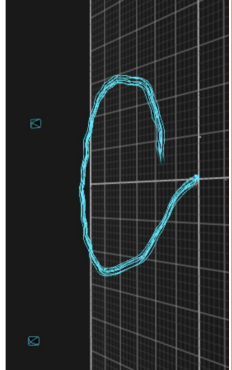
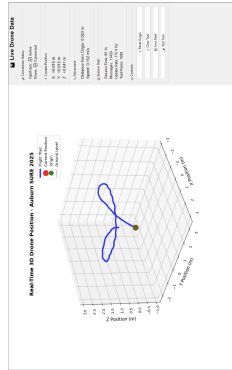


TESTING AND VALIDATION

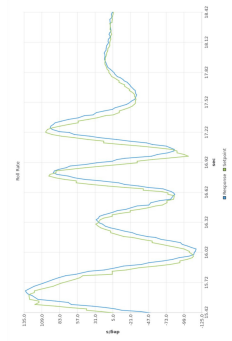


RESULTS AND ANALYSIS

The OptiTrack motion capture system successfully recorded and visualized the drone's 3D position throughout the flight session. As shown in the top image, the drone's trajectory was plotted in real time using a Python-based GUI, centered at the origin and smoothed using a moving average. The true trajectory demonstrates positional accuracy, where the same circular path is confirmed through OptiTrack's native software, where a clean circular path with minimal jitter is evident, validating the accuracy of the smoothed visualization.



The waveform in the image below reveals that the drone can closely follow oscillatory inputs, maintaining alignment with low lag. These results validate the effectiveness of the tuned PID parameters in achieving smooth and responsive roll dynamics, which are essential for precise autonomous flight. The low error (e.g., square or circle), and the corresponding change of the error.



DISCUSSION

- The PX4 firmware was successfully configured and the drone demonstrated stable flight after PID tuning. The tuning process revealed that even small adjustments to gains significantly impacted stability, emphasizing the importance of carefully balancing responsiveness with control smoothness.
- One thing to note is the significant drift caused by the drone. While we were able to successfully get the drone to smoothly start, it still experienced significant drift in the x/y directions.
- Integrating the OptiTrack system allowed for precise 3D tracking. Static position tests showed sub-centimeter jitter, confirming high positional accuracy. During dynamic tests, the motion path closely matched expected movement, validating the system's ability to serve as a reliable positioning source.
- One key insight was the challenge of real-time feedback integration. While motion data could be observed and logged, the next step is achieving live feedback control via MAVLink.



- Overall, the results demonstrate the platform's viability as a foundation for precise indoor autonomous flight. The work lays strong groundwork for future experiments.

FUTURE WORK

- Expand control to include being able to track multiple drones and control each individually.
- Compare Motion capture system vs Onboard SLAM system to determine which has better consistency and accuracy
- Add waypoints and trajectory planning integration to be able to perform autonomous missions. Additionally, add user-guided autonomous actions.

KEY REFERENCES

- PX4 Developer Documentation: dev.px4.io
- Mission Planner Guide: ardupilot.org
- MAVLink Protocol Documentation: mavlink.io
- OptiTrack Motive Software Guide
- Efficient model of PID controller of unmanned aerial vehicle: <https://arxiv.org/abs/1808.07193>
- PX4 For Beginners by Panfless3D: <https://www.youtube.com/watch?v=7Z5OUVEX>
- Control System for Unmanned Aerial Vehicles: <https://www.researchgate.net/publication/338480072>
- MAVLink: <https://mavlink.io/en/docs/1.0/protocol/protocol.html>
- HoYoBro QAV250 Setup Tutorial: <https://www.youtube.com/watch?v=U83Y1G4HW7s>