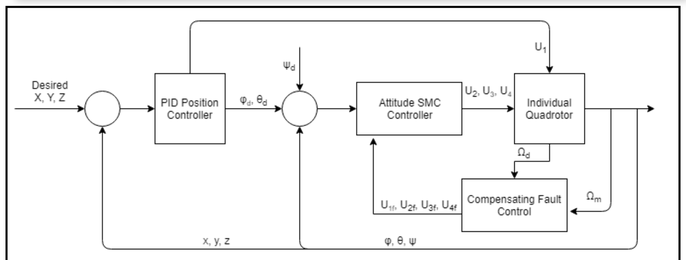
QUADSAT SWARM

ME: Aaron Cantara, Richard Heath, Benjamin Henry, Ravi Patel, Jacob Remick, Joshua Wallace
CS/ECE: Kyle Brewster, Michael Goulet, Sean Mackenzie, Jimmy Trinh, Keith Nason
Graduate Advisors: Sital Khatiwada, John McCormack, Alex Cook
Faculty Advisor: Dr. May-Win Thein

Abstract

QuadSat Swarm is a multidisciplinary senior project research group consisting of ME, CS and ECE seniors and underclassmen. The goal of this research project is to develop quadrotor systems to be used as economical Earth-based satellite test platforms to research and develop effective on-board spacecraft control algorithms. This fleet of quadrotors will employ graduate student nonlinear attitude control theory as well as Artificial Potential Field (APF) algorithms to autonomously achieve user-designed swarm formations.

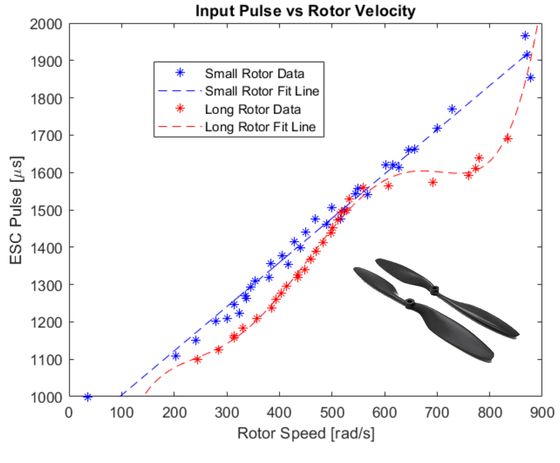
Quadrotor Control Scheme



Current State: Quadrotor Control Loop

- Linear Proportional Integral Derivative (PID) controllers used for altitude and position control
- Nonlinear Sliding Mode Control (SMC) being implemented for attitude control

Rotor Speed Analysis



Rotor mechanical fault (flexing) observed at high rotor speeds.

System Overview

Sensors

9 DOF Inertial Measurement Unit

Custom IR Sensor

MS5611 Barometer

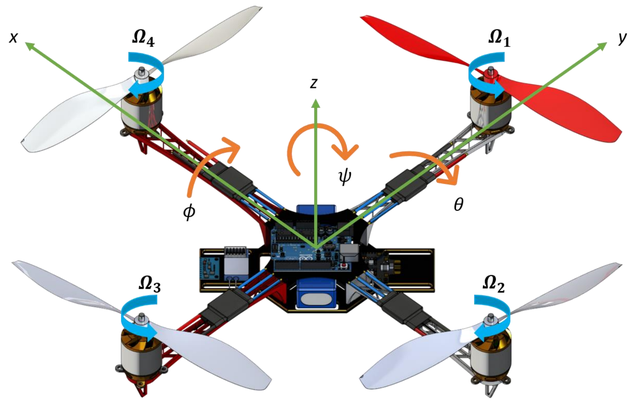
Adafruit Ultimate GPS

Marvelmind Indoor GPS

3D-Printed Fixtures

Swarm Algorithm

$$V_i(\mathbb{X}) = \sum_{j=1}^{N} \left(\frac{k_a}{2} \|\hat{x}_i - \hat{x}_j\| + \frac{k_r r}{2} e^{-\frac{\|\hat{x}_i - \hat{x}_j\|^2}{r}} \right) + \frac{k_{a,L}}{2} \|\hat{x}_i - \hat{x}_L\| + \frac{k_{r,L} r_L}{2} e^{-\frac{\|\hat{x}_i - \hat{x}_L\|}{r_L}}$$

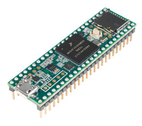


Swarm

- Decentralized Artificial Potential Field (APF) for swarm coordination on central PC or Raspberry Pi
- Python-based interface

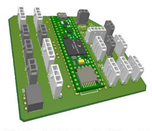
Raspberry Pi/ Ground Station PC

Microcontroller



Teensy 3.5

- 50+ pins
- Multiple serial pin connections
- 32-bit (Arduino Uno is 8-bit)
- 7.5x faster processing speed than Arduino Uno



Custom PCB

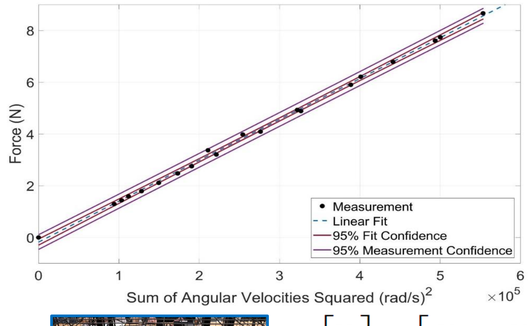
Communication

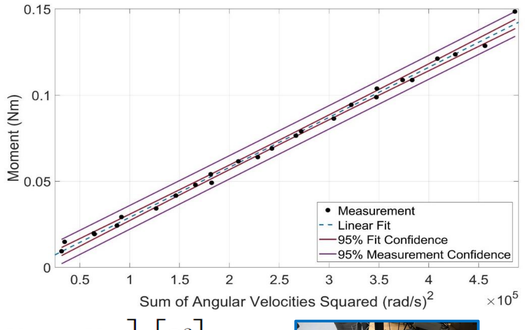
Xbee S1

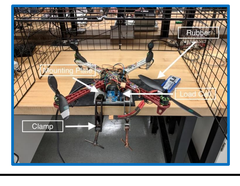
- Serial and radio
- Transmits and receives data on command
- Isolated communication network

Aerodynamic Constants

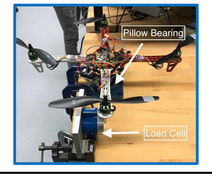
K_f and K_m were experimentally determined using a custom mounted bearing and a load cell.







$$\begin{bmatrix} U_1 \\ U_2 \\ U_3 \\ U_4 \end{bmatrix} = \begin{bmatrix} K_f & K_f & K_f & K_f \\ 0 & -K_f & 0 & K_f \\ K_f & 0 & -K_f & 0 \\ K_M & -K_M & K_M & -K_M \end{bmatrix} \begin{bmatrix} \Omega_1^2 \\ \Omega_2^2 \\ \Omega_3^2 \\ \Omega_4^2 \end{bmatrix}$$



Swarm Implementation

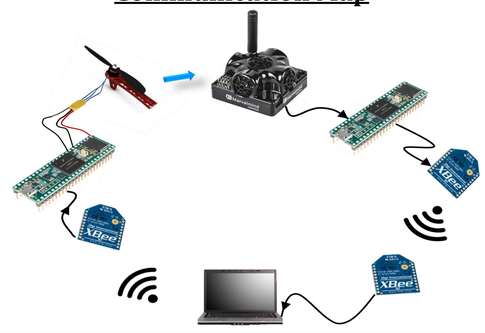
Hardware & Electrical Design
- Construction and assembly of 5 quads
- Introducing hardware & sensors

Autonomy Development
- Implementing linear & non-linear controls
- Attitude and position feedback

Swarm Communication
- Introducing hardware to send/receive data
- Ground station computing algorithm

Autonomous Cohesive Motion

Communication Map



Applications

This project aims for an economic alternative to costly research-based autonomous quadrotors. Industries that can benefit from this include:

- Aerospace Research, Modeling and Testing
- Agriculture
- Search & Rescue
- Defense
- Infrastructure Inspection
- Security Monitoring
- Surveying & Mapping
- Aerial Imaging

Acknowledgements

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