# Exploring Satellite Dynamics and Controls Through Quadrotors


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## Abstract


Our capstone senior project, Quadsat, has been working on stabilizing quadrotors with the end goal of using them as platforms for studying satellite constellation flight. The project is multidisciplinary, and we incorporate computer science, mechanical engineering, aerospace engineering, and electrical engineering principles into our design. Our design incorporates a wide range of avionics, including radios, DC motors, electronic speed controllers, and various sensors, interfacing these electronics with mechanical components to form a fully autonomous system.

We have been focusing the main part of our effort on the controls that allow for altitude control and for stabilization, along with a side project to achieve live video feed. We have achieved robust altitude control using fuzzy logic utilizing sensory input from an ultrasonic sensor. We have created a live video feed system which transmits camera footage via a 5.8GHz frequency to either an LCD screen or a phone.

We have also focused on miniaturizing the system, with a final system which weights 638g as opposed to the 1220g of the original design, a reduction of roughly 50% of the weight.


## Background

Quadrotors are four rotor flying robots that can be controlled either autonomously or using a radio communicator. These robots are highly agile with six degrees of freedom but are also extremely unstable. Due to the high instability of these robots, they require a control system on board to allow for flight. This control system takes in data from sensors and makes calculations to determine what adjustments the motors should make. These adjustments are done several hundred times per second and account for roll, pitch and yaw rotations.

Quadrotors have been increasingly used in a wide array of real world situations recently, from military surveillance, to photography and video in production films. These different situations require quadrotors of various sizes and with various different auxiliary sensors and thus we have worked to make several different models, each at a different size scale.

Our quadrotors are designed to function in either an autonomous mode or in a manual control mode. The quadcopter also has a live video feed system, allowing for increased operator based functionality.

## Components

### Mechanical

- Chassis
- Propellers
- Antennas

Chassis

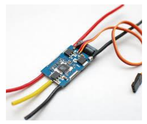
### Electrical

- Radio system for control inputs (2.4GHz)
- Radio system for live feed camera (5.8 GHz)
- Microprocessor
- Power distribution system
- DC brushless motors
- Electronic speed controllers
- Sensors (Gyroscope/IMU, ultrasonic sensor, pressure sensor, etc.)

Arduino Uno

Gyroscope

DC Brushless Motor



Electronic Speed Controller (ESC)

**Arduino Uno (Brains of the Quadcopter)**
- Contains digital and analog input & output pins. ATmega328 microprocessor. 16MHz clock speed.

**Gyroscope**
- 3 axis of rotation. The orientation of the gyroscope is used to stabilize the quadcopter.

**Brushless Motors**
- Contains 4 brushless motors that spin individually, depending on the AC output of the ESC.

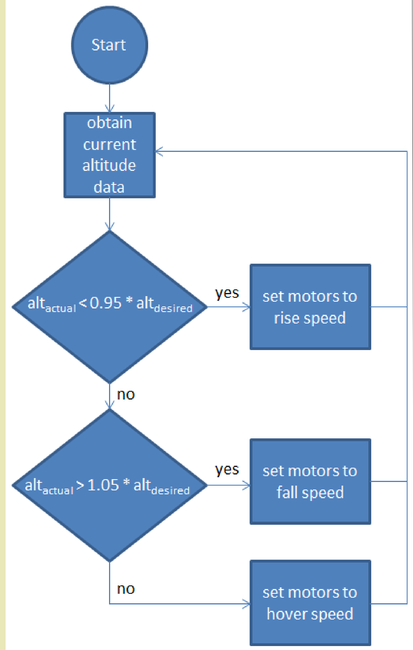
**Electronic Speed Controller**
- Measures the pulse width specified by the PWM pins of the Arduino. The outputs of each ESC dictate the rate of rotation for each of the motors

### Altitude Control Methods

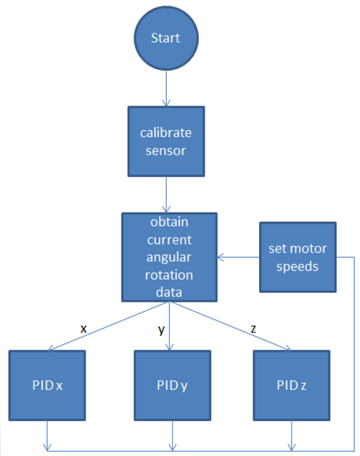
| Ultrasonic Sensor | Barometer Sensor |
|---|---|
| Advantages:<br>• No calibration needed.<br>• Easy conversion between different units of measurement.<br><br>Disadvantages:<br>• Susceptible to loud noises, that could interfere.<br>• Foam or soft objects can absorb sound waves.<br>• Extreme changes in surrounding temperature can alter the speed of sound through the air. | Advantages:<br>• Requires less power<br>• Individual 32 bit processor (more precise)<br>• More accurate regardless of ground shape<br>• Smaller and less weight<br><br>Disadvantages:<br>• Susceptible to interference from pressure caused by propellers<br>• Can be affected by the amount of humidity in the air.<br>• Needs to be better protected and shielded to mitigate outside effects. |

## Flowcharts

### Altitude



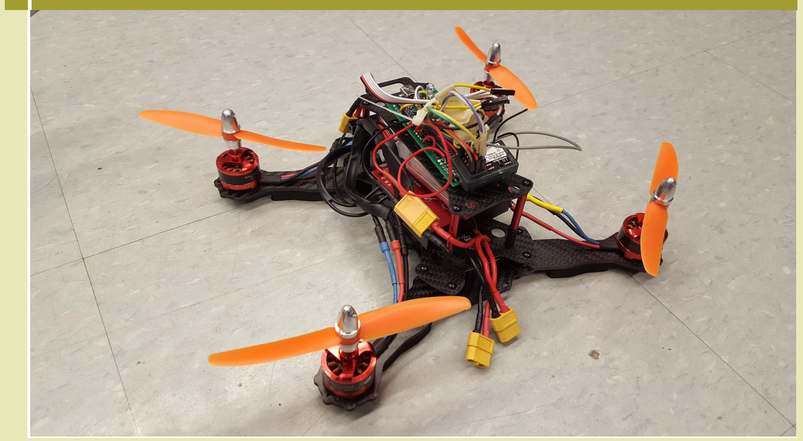

### Stabilization




**Legend**

$E_t$ = Most Recent Error
$E_{t-1}$ = Last Error
$P = K_p * (E_t - E_{t-1})$
$I = I_t + K_I * (E_t - E_{t-1})$
$D = K_D * [ (E_t - E_{t-1}) - (E_{t-1} - E_{t-2}) ]$
Output = P + I + D
alt = altitude

## Results



## Issues Faced

- Fragile electrical system within a dynamic vibration and impact heavy system
- Important weight restrictions due to limitations on thrust capabilities
- Lack of access to equipment needed to properly balance a quadcopter
- Lengthy shipping times on parts that are in need of replacing broken parts
- Steep learning curve for programming languages and new technologies
- Maintaining strong communication in the large multidisciplinary team
- Nonlinearities including ground effects
- “No Fly Zone” rules set for drones at UNH preventing testing outdoors

## Conclusions

**Finished**

- Miniaturizing quadrotor system to 50% of overall weight as compared to past years' models.
- Live video feed system developed to forward camera footage to either an LCD screen or any smartphone/tablet.
- Altitude control successfully developed using fuzzy logic.
- The Arduino platform proves to be an effective and cost efficient micro controller for the project.

**Ongoing**

- Stabilization is ongoing and initial tests are promising but further development is needed.

**Future Years**

- Formation flight with multiple quadcopters.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