



# Autonomous Quad-Rotor Formation Design

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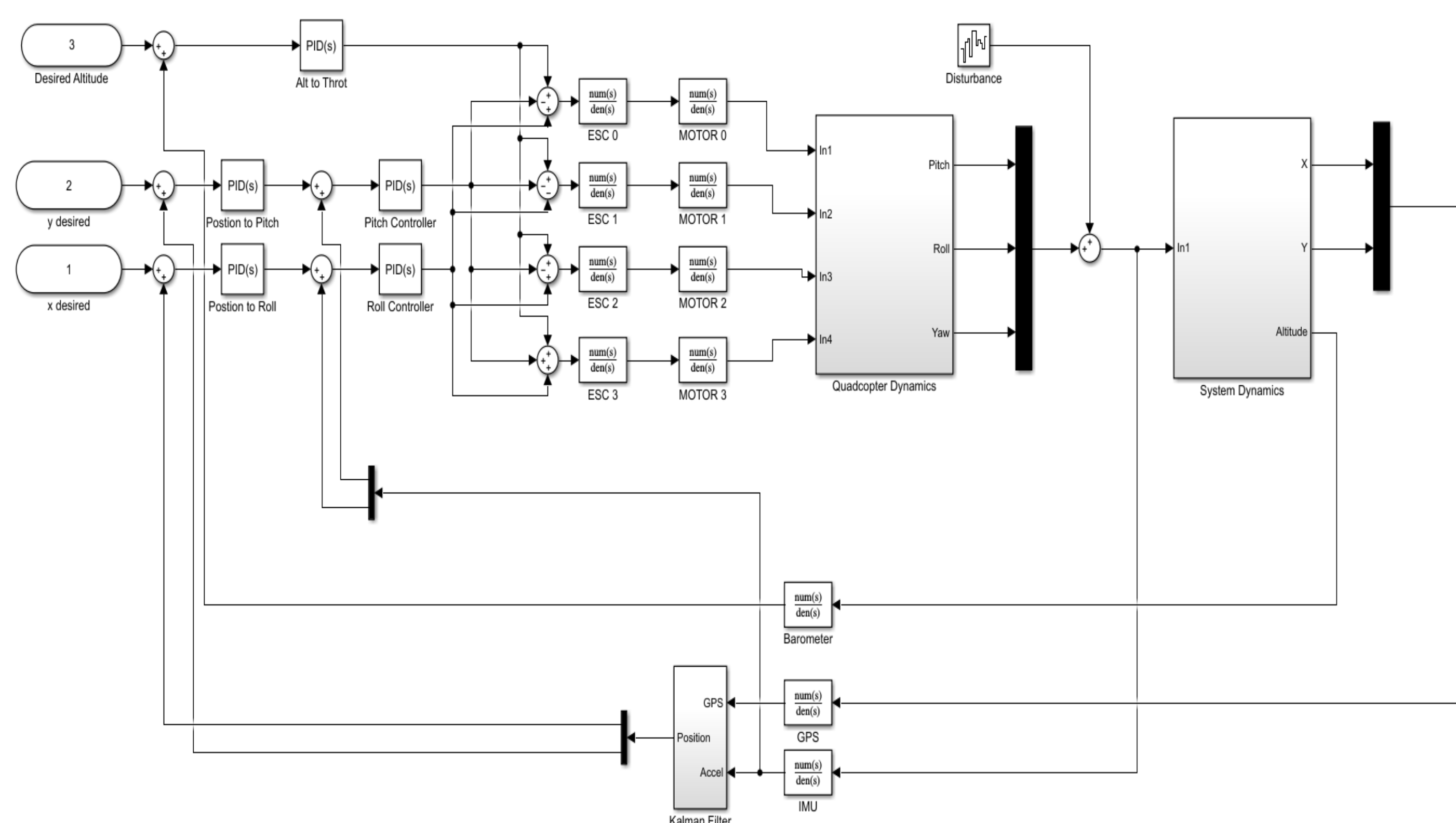
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## Introduction

Four quadcopters were designed to fly in formation and follow a GPS signal. Formation flight allows them to perform tasks at the same time in different locations. These tasks could include tracking, mapping, and data collection. Using a leader-follower system, the UAV's can change direction and speed without crashing into each other. The control system specifies a single quad as the leader and has all others follows its orders. The implementation creates a stable environment for testing and allows the quads to work together with full autonomy. The use of this system for tracking and data collection has many applications that the team will expand upon.

## Feedback Control Loop



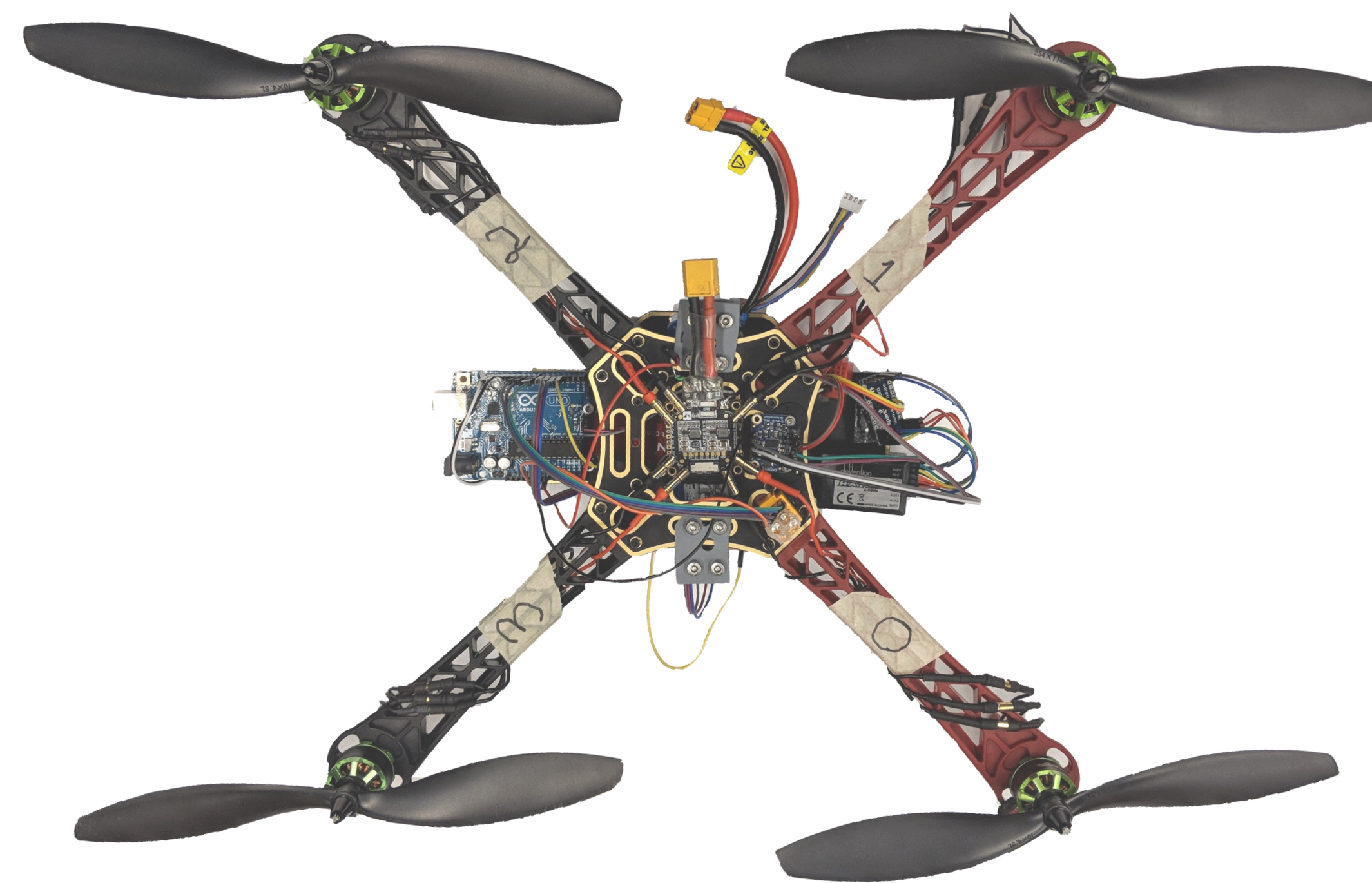
## Position & Attitude Control

- Controllers are implemented to allow the quadcopter to remain steady when flying
- A PID Controller is a feedback mechanism which calculates an error value and then applies a correction signal to the system
  - Proportional: control the speed of response
  - Integral: minimize steady-state error
  - Derivative: control to minimize overshoot

$$u(t) = K_p e(t) + K_i \int_0^t e(t) dt + K_d \frac{d}{dt} e(t)$$

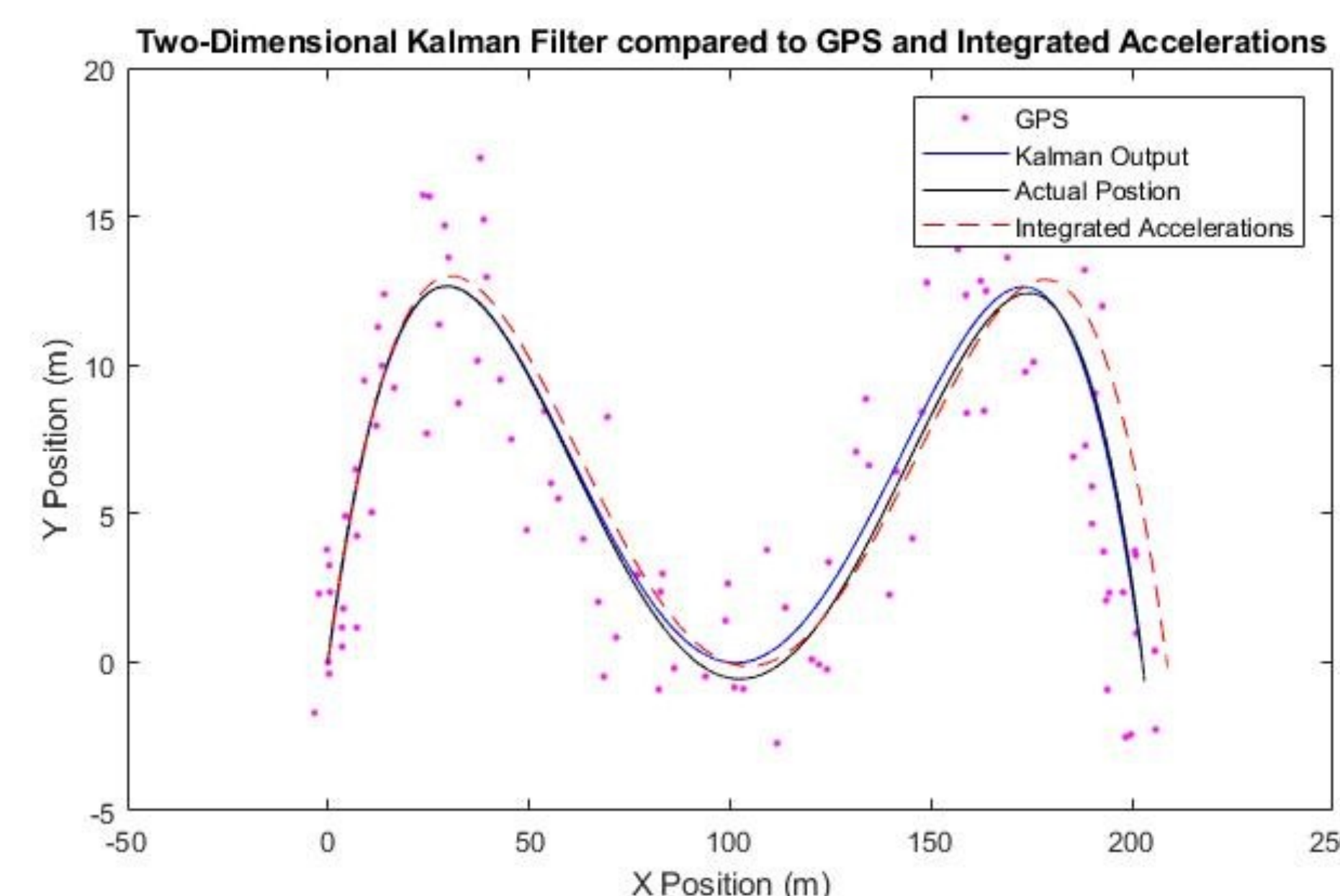
## Design

- Processors and Sensors
  - Arduino Uno Rev3 : Flight Controller
  - Adafruit MTK3339 GPS Module : Position Measurement
  - Adafruit BNO055 Inertial Measurement Unit (IMU) : Orientation Measurement
  - Raspberry Pi : Autonomy Software
  - SparkFun MPL3115A2 Barometer: Altitude Measurement
  - Digi XBee Radio Communicator : Signal Communication
  - 3-D Printed Component Housing Allowing Custom Sensor Fixture



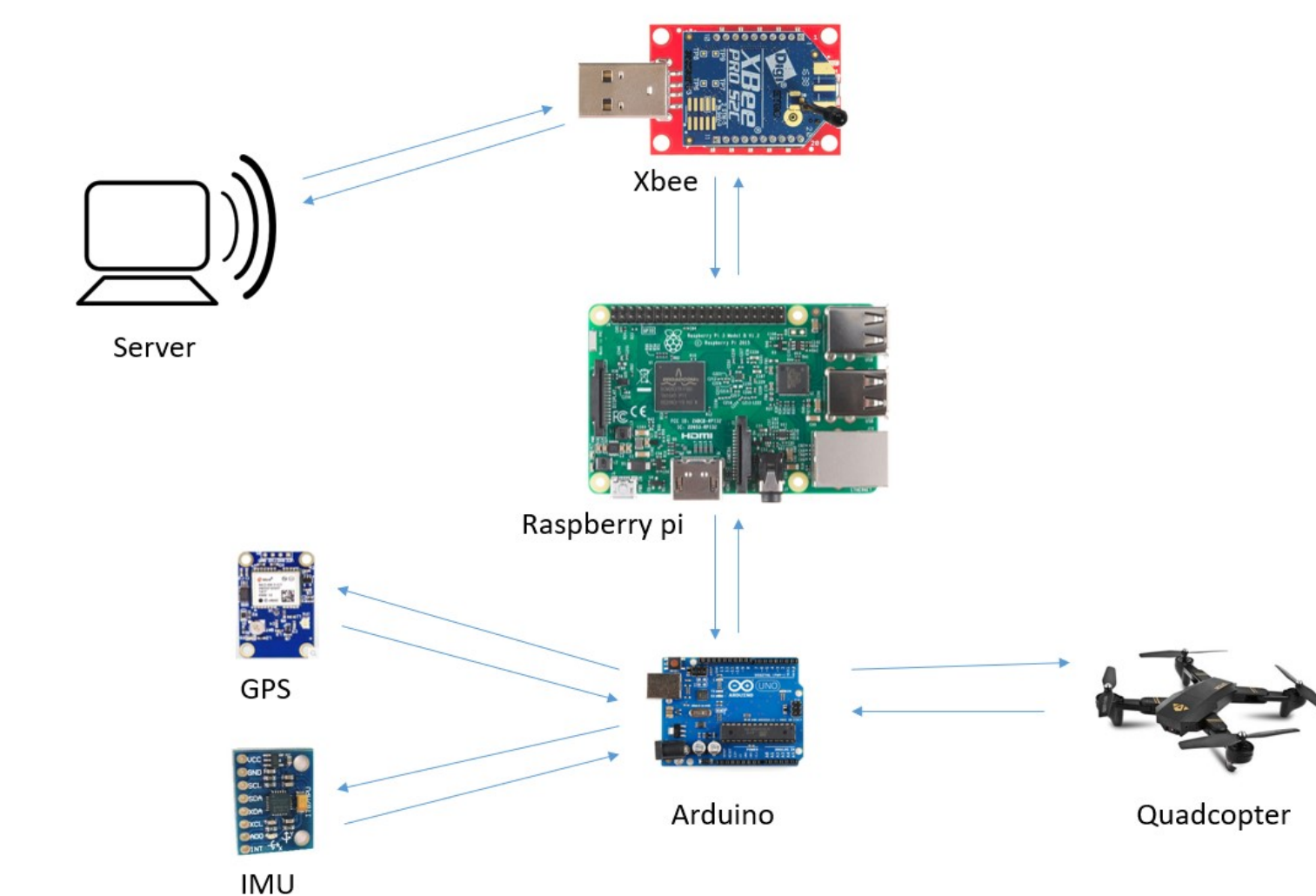
## Results

- A modular flight controller program was developed from the ground up, allowing edits and upgrades to be added to the existing system without disrupting the framework
- A fully functioning rate control quadcopter was built and tested to satisfy the design criteria
- A time-varying, extended Kalman Filter was designed to create a more accurate value for position using sensor fusion of the GPS and IMU



## Autonomy & Communications

- Communication between the Server, Raspberry Pi, and Arduino is all done via serial
- XBee modules through USB are used as the interface between the Server and Raspberry Pi. UART is used between the Pi and Arduino.
- Autonomy is achieved by giving a list of location (x, y, z) deltas to the Server and following these steps:
  - The server sends the next location delta in line to the Pi as a JSON string and waits until a variable number of messages are received.
  - The Pi parses the deltas from the JSON and sends them to the Arduino.
  - The Arduino uses the deltas to move the quadcopter accordingly. As the quadcopter moves, it periodically sends its current location back to the Pi.
  - Once the current location is within a margin of the destination, a message is sent back to the Server and the Pi waits for the next location delta from the Server.
  - When the Server receives a variable number of messages the process repeats until all location deltas have been sent.



## Future Work

- Collision avoidance protocol
- A neural network using image recognition
- Object tracking guidance systems

## Acknowledgements

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## References

Czerniak, G. (2018). *Greg Czerniak's Website - Kalman Filters for Undergrads 1*. [online] Greg.czerniak.info. Available at: <http://greg.czerniak.info/guides/kalman1/> [Accessed 16 Apr. 2018].

ElKholi, H. (2014). "Dynamic Modeling and Control of a Quadrotor Using Linear and Nonlinear Approaches," M.S. Thesis, School of Sciences and Engineering, The American University in Cairo.

J. M. Brokking, "Brokking.net - My personal project page.," Brokking.net - My personal project page. [Online]. Available: <http://www.brokking.net/>.