# QuaSAr

## Quadrotor Swarm Arena

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### Abstract

This study discusses the modeling and simulations carried out to design and tune a control system for autonomous micro-quadrotor vehicles (MQVs)and the construction and implementation of a testbed for flight testing of the control system. Unmanned Aerial Vehicles (UAVs) will be implemented in an MQV swarm, requiring agents to achieve stable autonomous, point-to-point navigation and trajectory tracking. Modeling methodology is presented along with the selected controller design. Various maneuvers are investigated to assess the ability of the UAV under control. These maneuvers include hoover, constant-speed translation, and constant yaw rate maneuvers. Additionally, navigation performance is assessed using a profile representative of those expected during swarm operations. The control algorithm uses feedback data from different components of the testbed. The testbed is comprised of an Optitrack Flex 13 motion capture system, Crazyflie 2.0 nano-quadcopters, and a user-friendly Ground Station. Each of these components is interfaced through our communication system. The testbed is functional and single quadrotor flight testing has begun.

### Background

The Quadrotor Swarm Arena (QuaSAr) test bed was specifically developed with the intention of conducting research in control theory via the flight of quadrotors. Quadrotors are excellent candidates for control theory research because of their inherent instability. The ultimate goal of this project is to form a completely autonomous quadrotor swarm, complete with individual sensing capabilities as well as full system communication. This is an ideal test bed for student run university research in control theory because of its easy accessibility.

### Purpose & Objectives

Purpose

– Develop the capability at ERAU to study and develop swarm control law.

Objectives

– Make considerable progress in the development, design, and construction of a functioning quadrotor testbed

– Integrate a trajectory acquisition system

– The system must be safe for spectators, developers, and the testbed assembly

### Test-Bed Overview

The developed swarm control testbed is comprised of three main components:

– Quadrotor Agents

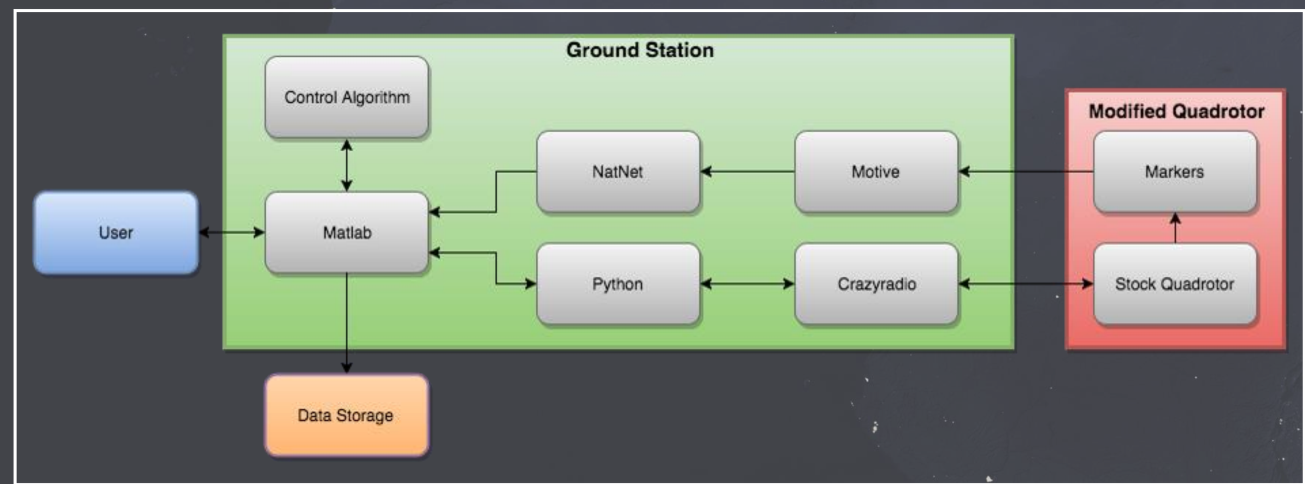
– Motion Capture System

– Test Control/Ground Station

Users configure and control tests from the ground station. This “hub” is the collection of numerous applications developed in a number of programming languages to establish information paths between components.

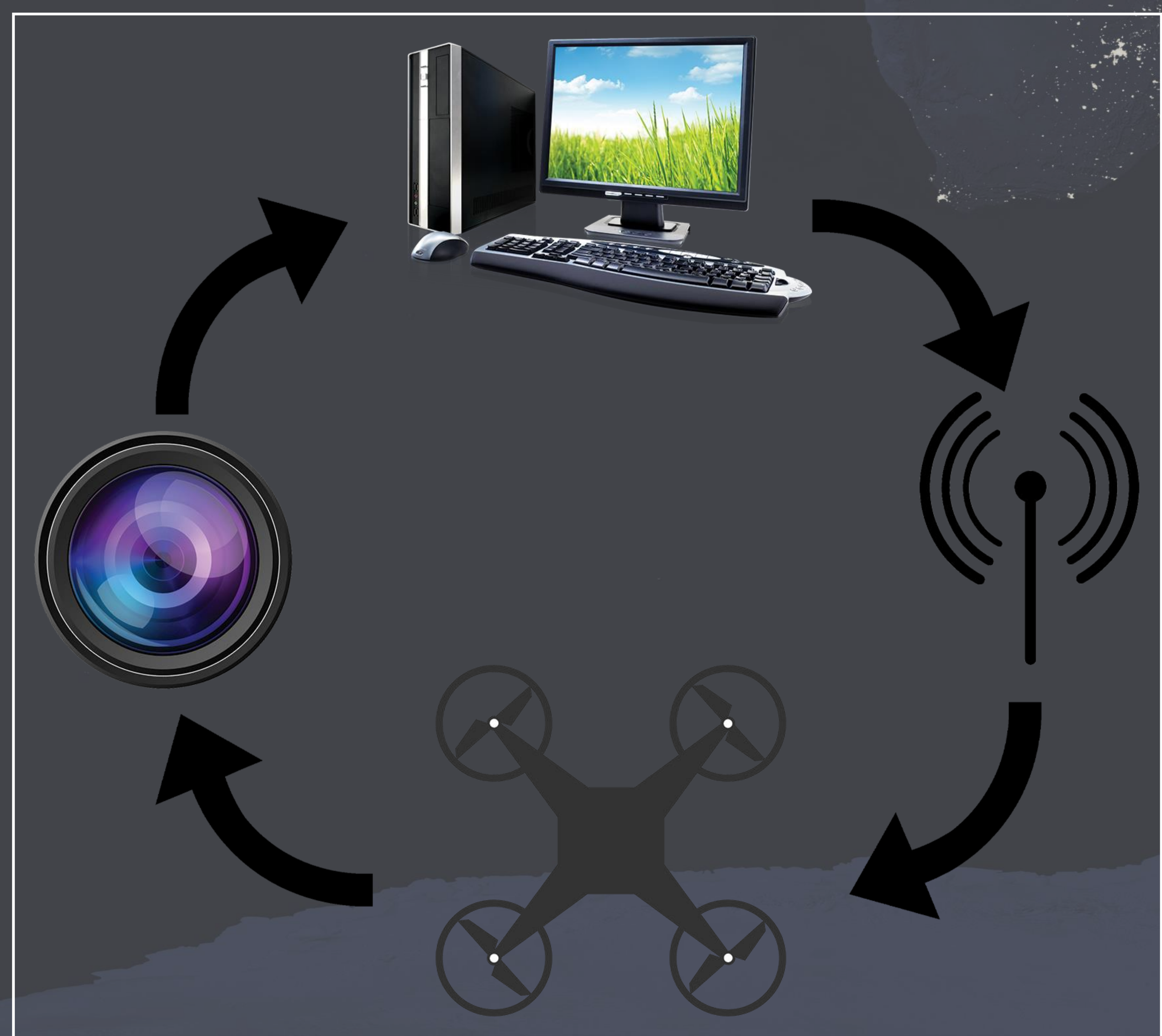
The primary software platform for the ground station is built using Matlab and Simulink. This application serves as the “central hub” for all data processing and messaging. NatNet and ZeroMQ communication protocols are used to establish connections between the Matlab ground station and respective subsystems.

### System Architecture




*The diagram above is a high-level, technical representation of the communication pathways present in the system. It should be noted that the input and output with the modified quadrotors is completely automated.*

*The diagram below represents a high-level, graphical representation of the communication pathways present in the system. The cameras observe the quadrotors, where information is sent to the ground station, and the ground station commands the quadrotors wirelessly, and the cycle continues indefinitely.*



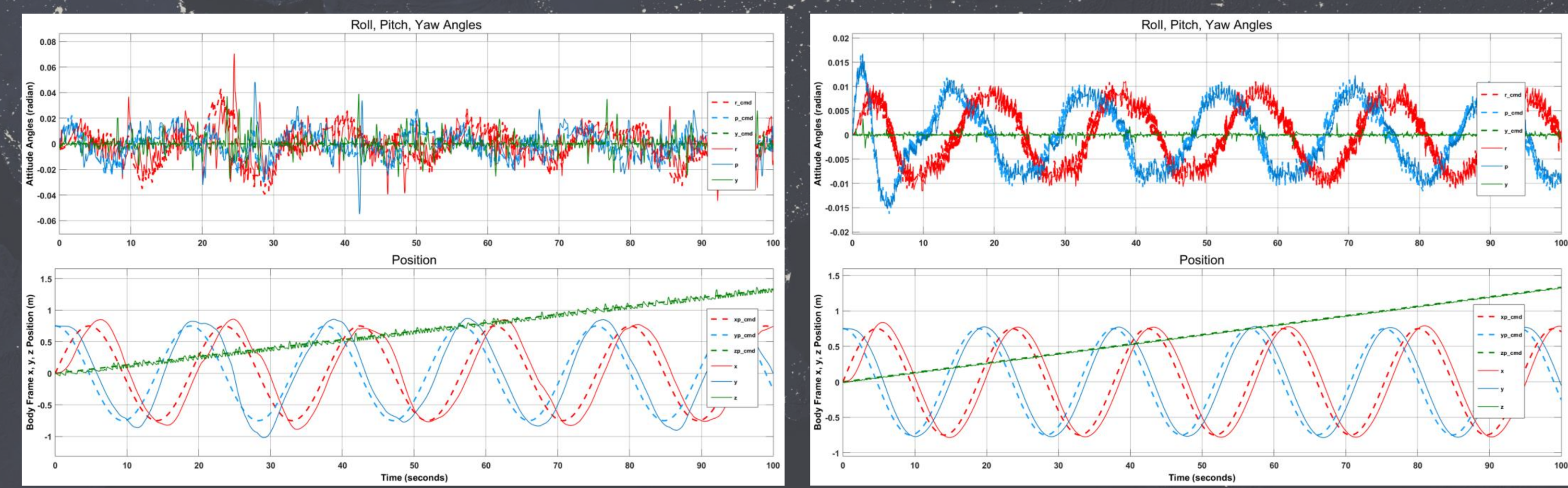
### Simulation & Results

Simulations were conducted using MATLAB and Simulink to predict system performance and test-bed requirements. The full, nonlinear quadrotor dynamics were modeled and tested using a simple combination of cascaded PID controllers. Simulations were used for two primary items:

– Select/test quadrotor control law

– Determine test-bed performance requirements

These simulations showed that the selected cascaded PID controller was adequate for stabilizing quadrotor agents.




Additionally, the results show that a refresh rate of 10 Hz (*left*) is necessary for reasonable agent performance. This realization confirms that the developed system will meet the needs; the measured refresh rate is approximately 30 Hz (*right*).

### Conclusions

The developed system meets all the initial objectives.

Flight testing of quadrotor agents is currently under development.

### Future Work

The next step for QuaSAr is to improve the quality and reliability of all the communication paths. This work includes the reduction of external source dependencies and the refinement of current ground station methodology. In addition, the actual

### Acknowledgment

We would like to thank the following sponsors, whose generous contributions made our research possible: