

# CS486C – Senior Capstone Design in Computer Science

## Project Description

<b>Project Title:</b> Control and Visualization for Drone Research	
<b>Sponsor Information:</b> Intelligent Control Systems (ICONS) Laboratory	Truong X. Nghiem, Assistant Professor School of Informatics, Computing and Cyber Systems Northern Arizona University Email: <a href="mailto:truong.nghiem@nau.edu">truong.nghiem@nau.edu</a> Phone: 928-523-4973

### Project Overview:

Drones, or unmanned aerial vehicles (UAVs), are seeing and will see numerous applications, in transportation, delivery, infrastructure inspection, medical emergency, entertainment, and many other fields. In the future, autonomous drones will become ubiquitous, potentially causing many safety, security, and traffic control issues. The Intelligent Control Systems (ICONS) Laboratory at NAU develops foundational theory, methods, algorithms, and applications of intelligent control. Currently we are developing a multi-drone research platform in the lab. For a short demonstration of the platform, see: <https://youtu.be/r1H-Pqc4dPY>



Current research in autonomous drones focuses on advanced control and planning algorithms for multiple drones (a swarm of drones) to carry out complex tasks in a complex environment with obstacles and sophisticated safety requirements. There exist good open-source simulation and visualization tools for experiments in such research areas. However, there are still several challenges:

1. **Task and environment configuration:** complex tasks and environment configurations require sophisticated specifications, typically in complex mathematical forms. In a dynamic environment, when obstacles can change and move, the specifications are even more complex. Currently, researchers must formulate these specifications manually (that is with pen and paper) and input them into control code in some way (usually they are hard-coded in the control source code, or written in some obscure, long, and complicated text inside a file).
2. **Visualization:** existing tools allow visualization of a simulation / experiment in cartoonish graphics, while a video recording of an experiment does not show the virtual environment configuration (unless physical objects are placed in the space) or the computed flight paths. Usually, these video recordings must be edited later to manually add the graphics of the virtual environment.

### Objectives

This project aims to develop a software tool to address the first of the above challenges. In particular, we envision a GUI-based desktop application running in a Linux environment that serves as a comprehensive, easy to use graphical interface “wrapper” for the underlying suite of open-source tools for multiple-drone planning. Key features of the completed product will include:

- **Backend:** the backend will be a *software framework inside the Robotic Operating System (ROS), running on Linux (Ubuntu)*. ROS is the most widely used open-source middleware for robotics and is used in our lab for the drone research platform. The backend will streamline the process of simulating / experimenting drone control algorithms. Its key features include:
  - Allow source files (in C++, Python, Julia, etc.) that implement drone control algorithms to run in a simulated or real environment.
  - Manage the input - output between user control code and drone simulators or real drones.

- Record real-time data from the drone simulators or real drones.
- Provide a safety mechanism for drones, for example if the user code fails, the drones will be landed safely and the experiment stops.

Though these features sound complex, most of the necessary software components to build the backend are already available in ROS. The main tasks would be software design and integration.

- **GUI:** the GUI will be a desktop application, running on Linux (Ubuntu), which allows for
  - Intuitive input of the task specifications, and translation into the mathematical forms that the user control algorithms can accept.
  - Intuitive configuration of the virtual environment, saving and loading environment configurations to and from files, and translation into mathematical constraints for the control algorithms.
  - Control and visualize simulations / experiments in real-time.

In sum, powerful software tools for planning and controlling multiple-drone operations exist, but are arduous to configure and use by end-users. Our aim here is to produce a power GUI “wrapper” for these software tools, providing end-users with quick and user-friendly configuration and operation. The software will be useful for autonomous drone control researchers, making it much easier and more intuitive to perform drone research experiments.

### **Knowledge, skills, and expertise required for this project:**

- Software development skills and programming skills in Python and/or C++, including GUI development. Knowledge of Matlab is a plus.
- Familiarity with Linux and building programs from source code in Linux.
- Experience with basic electronics, embedded systems, and/or robotics and/or ROS is an advantage.
- Knowledge of visualization and/or 3D computational geometry is a big advantage.

### **Equipment Requirements:**

- The sponsor will provide the drone hardware & software. Students may have access to the HPL lab for testing drones with a camera-based tracking system.
- Otherwise, there should be no equipment or software required other than a development platform and software/tools freely available online.

### **Software and other Deliverables:**

- The software applications as described above, deployed and tested successfully with real drones. Must include a complete and clear User Manual for configuring and operating the software.
- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development of the product.
- Complete professionally-documented codebase, delivered both as a repository in GitHub, BitBucket, or some other version control repository; and as a physical archive on a USB drive.