Development of an Automated Wind Field Calibration System Using UAV and Motion Capture for WindShaper Evaluation

Problem Statement

Accurate wind field generation is critical for controlled aerodynamic testing and UAV experimentation. The WindShaper system enables programmable airflow generation; however, its performance must be carefully calibrated to ensure that the generated wind field matches the desired input conditions. Variations in wind intensity, directional deviation, spatial attenuation, and system response can significantly affect experimental accuracy.

Currently, there is a lack of automated, high-resolution calibration methods that can characterize the three-dimensional wind field within a defined test volume. Traditional calibration approaches are often manual, time-consuming, and limited in spatial resolution.

This project aims to develop an automated wind field calibration system using a UAV equipped with onboard sensors and a motion capture system. The UAV will follow predefined scan patterns within a controlled test volume to measure wind intensity and direction across space. The system will evaluate key characteristics such as wind attenuation over distance, directional accuracy, and input-output response of the WindShaper system.

In addition, this project will serve as a hands-on educational platform for undergraduate students. Through the calibration process, students will gain practical experience in experimental design, sensor integration, system identification, and data-driven modeling, which are often difficult to fully understand through traditional coursework alone.

Overall Project Objectives

- Develop an automated wind field calibration framework for the WindShaper system
- Design UAV-based measurement strategies for capturing wind intensity and direction within a 3D test volume
- Integrate motion capture system for precise position tracking of the UAV
- Develop predefined scan patterns (grid, sweep, adaptive sampling) for spatial wind mapping
- Measure wind attenuation as a function of distance from the WindShaper
- Evaluate directional accuracy and deviation of generated airflow
- Analyze input-output response characteristics of the WindShaper system
- Develop data processing pipelines for wind field reconstruction and visualization
- Document calibration procedures and results to support future aerodynamic testing

Individual Team Member Responsibilities

Students will be recruited and assigned to the following roles:

- **Student 1 (Experimental Design & UAV Operations):**
  Design scan trajectories and UAV flight patterns; operate UAV within motion capture environment
- **Student 2 (Sensing & Integration):**
  Integrate wind sensing instruments (e.g., anemometer or IMU-based estimation) and motion capture data systems
- **Student 3 (Software & Automation):**
  Develop automated scanning and data collection system using ROS/MAVROS; implement trajectory control and synchronization

All students will collaborate on system integration, data collection, experimental validation, and documentation, ensuring a comprehensive and interdisciplinary research experience.

Faculty/Staff Mentoring

The mentoring approach will provide structured, hands-on research training through a phased process. Students will first receive training in UAV operation, motion capture systems, sensor integration, and experimental methods. They will then work under guidance to develop their assigned components, followed by independent contributions to system integration, automated testing, and data analysis.

Weekly meetings will be conducted to monitor progress and provide feedback. Individual mentoring will support technical development and problem-solving.

Through the calibration process, students will gain critical skills in experimental design, system identification, sensor fusion, data analysis, and validation of engineering systems. These skills are directly applicable to aerospace, robotics, and control systems research.

For dissemination, students will present their work at the MSU Undergraduate Research Symposium and contribute to technical documentation. The results are expected to support future publications and research proposals.

The developed system will also serve as an educational platform, enabling students to visualize and understand complex spatial wind field behavior and system response through real-world experimentation.