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Autonomous Flight of Fixed-Wing Aircraft Using Motion Capture

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VIP Vertically Integrated Projects AIDA³ WINDRACERS

Abstract

This research focuses on the development and testing of autopilot systems for lightweight fixed-wing Unmanned Aerial Vehicles (UAVs) within a controlled environment, utilizing the Purdue UAS Research and Test (PURT) facility. We propose a simple fixed-wing UAV using predominantly off-the-shelf components, replicating the characteristics of the Windracers fixed-wing aircraft, for comprehensive testing under various conditions. The aircraft utilizes an active LED marker board that is powered by the central battery and distinguishes and identifies individual aircraft, efficiently facilitating simultaneous operation of multiple units within the facility. The autonomous routine capabilities of the system are integrated with a nelly-constructed PID controller, which is simulated inside the Gazebo robotics simulation environment with a new high-quality 3D model of the aircraft.

The integration of autopilot technology in lightweight unmanned fixed-wing aircraft holds significant potential for various applications, including surveillance, monitoring, and data collection in challenging environments. The results of this research contribute to the advancement of autonomous aerial systems, offering a platform for further developments in the field of unmanned aerial vehicles.

Objectives

Objectives were split into a four-phase plan to prove the capability of autonomous flight, navigation and landing:

Phase A – Design an autopilot control system controlling off the shelf aircraft:

•We select a light-weight aircraft with small stall speed

•We design hardware in the loop control system

•Ground station computes ArduPilot commands and transmits them to the aircraft

•Aircraft performs operations, while having active markers on the wings

•Motion capture system monitors the motion of the aircraft and feeds ArduPilot with pseudo-GPS data

•We perform the testing of the aircraft and verify capabilities of the autopilot system

Phase B – Design an aircraft similar to Windracers

•Perform the sizing of the aircraft

•Go through the entire design process to create a scaled-down version of Windracers drone

Phase C – Implement ArduPilot to Windracers replica

Phase D – Replace ArduPilot with Windracers software

Acknowledgements

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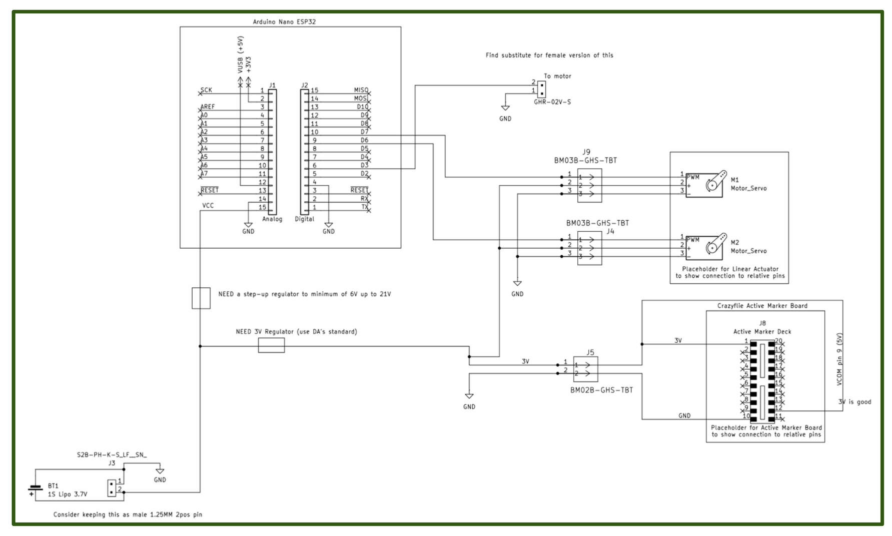
Design

Active Marker Board:

The onboard system now utilizes an active marker board. Prior to this semester, the system relied on a passive marker system for triangulation and data collection. While they eliminated extra cost and had no power requirements, this would not be effective for the goals of this project in the long term. Passive markers rely on external environmental factors to reflect the light necessary to display on the MOCAP system in PURT. On the other hand, active markers – while they require a power supply – are able to emit a strong, steady signal in environments with high interference, which the final output of this project is expected to maintain.

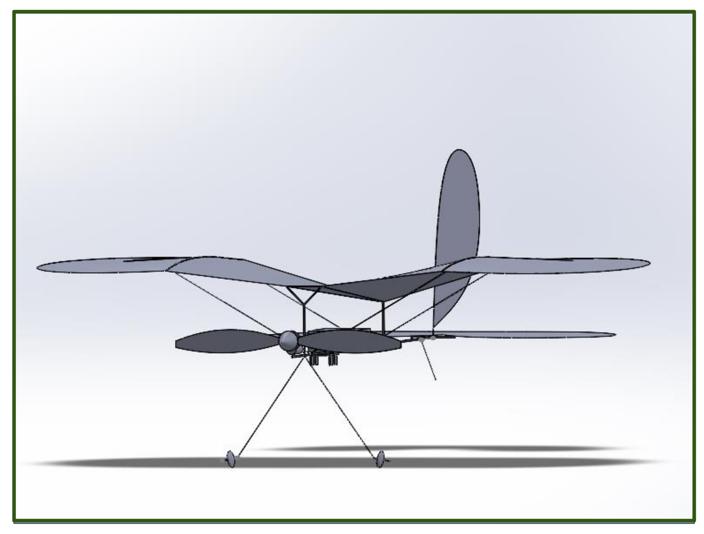
Aircraft Design:

The main airframe is a UMX Night Vapor. This aircraft fits our design needs because of its extremely light weight and slow stall speed. We attached the active marker board to the center of the aircraft to alter the center of gravity to our liking, along with LEDs on specific points on the aircraft's wings. These points are used by the motion capture system to determine the roll pitch and yaw of the aircraft during flight.



CAD Aircraft Design:

A simplified model of the Night Vapor aircraft that will be used was created using computer modeling software to be able to model the movements of the Night Vapors in Gazebo simulations.



Onboard Circuit Design:

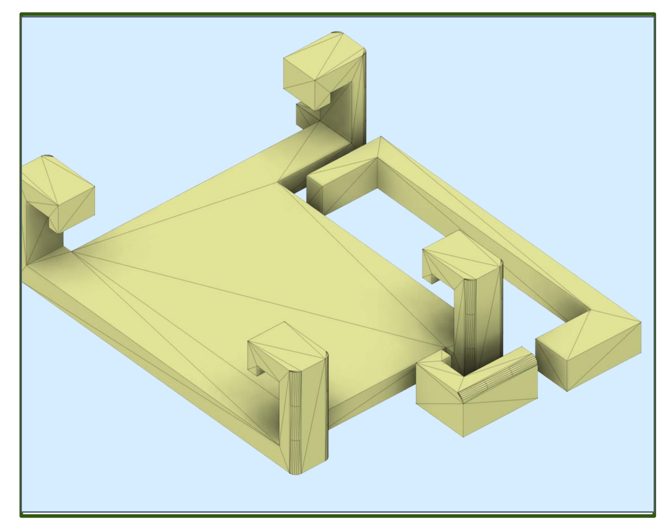
The final circuit design powered both the servo and active marker boards from the same supply.

We kept the stock battery and servo, as clearance was too tight for replacements.

To step up the 3.7V battery output to the required 5V, we used a step-up regulator.

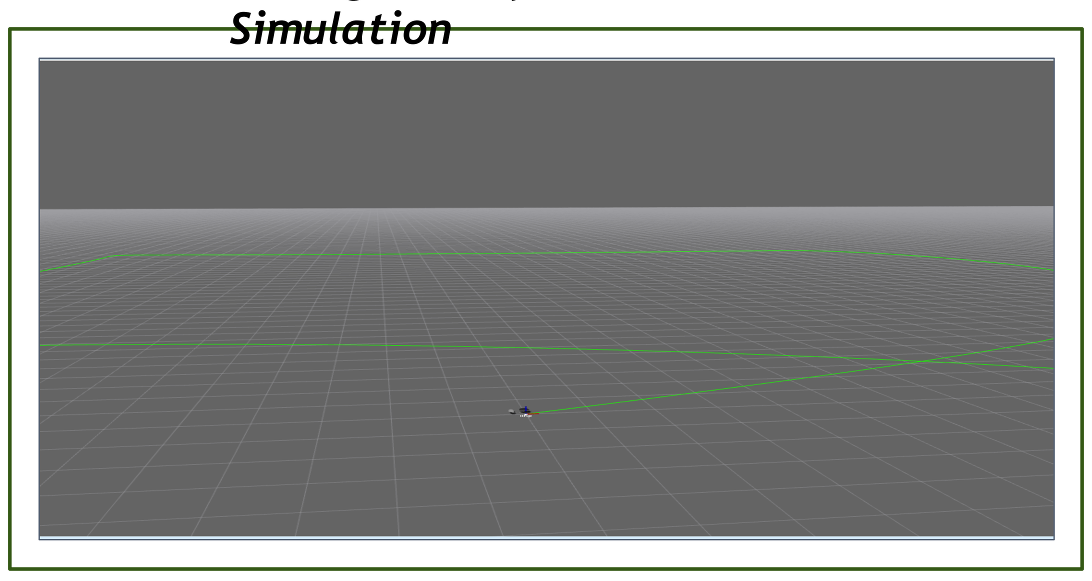
Mounted Bracket Design:

This bracket was designed to securely attach the active marker board to the UMX Night Vapor while still allowing the board to be quickly and easily removed. We decided to mount the active marker board to the bottom of the Night Vapor because it changed the center of gravity to better suit our goals, and it provided the most stable mounting to the aircraft.

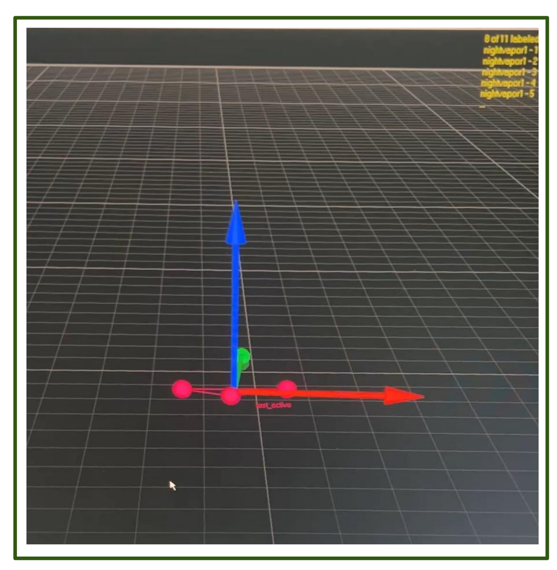


Results and Discussion

Fixed-Wing Aircraft Simulation



Active Marker Testing



The figures to the left illustrates the current state of experimentation. A generated trajectory displayed in green within the simulation environment. The CAD model of the Nightvapor is rendered in the simulation and the simulation can be directly interacted with using ROS2 packages just like the physical drone. Also, when the electronics are mounted on the Nightvapor, the motion capture software is able to use the mounted active markers to define a rigid body on the plane, which will be useful for further autopilot simulations.

Future Work

- Run simulations in Gazebo with the created CAD Nightvapor model
- Integrate autopilot software along with the motion capture facility
- Test the course planning in PURT
    - Be able to fly multiple aircraft simultaneously without collisions
- Continue communication with Windracers to optimize current project with the needs of the company
- Start designing an aircraft similar to Windracers
    - Perform aircraft sizing
    - Create a scaled-down version of the Windracers drone
- Use CogniPilot based simulation to tune the control gains of the Total Energy Control System (TECS)
    - Be able to closely follow a pre-determined trajectory

Resources

Windracers

- Windracers is a company focused on providing humanitarian resources to locations where there is poor transportation
- Received advice and technical help from a PCB engineer from Windracers
- https://windracers.com/

Purdue UAS Research and Test Facility (PURT)

- -600,000 cubic feet airport hangar equipped with motion sensors for precise tracking of drone movements
- https://engineering.purdue.edu/PURT

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