YUAA Active Adjustment Ornithopter

[anonymized project leader name]

November, 2020

Abstract of Proposed Activities

Summary

An ornithopter is a flying machine which generates thrust and lift by imitating the flapping motion of birds. While ornithopters have greater maneuverability and stealth compared to traditional aircraft, they are much less efficient. The Yale Undergraduate Aerospace Association (YUAA) will design and build an ornithopter using active adjustment systems to improve efficiency. Active adjustment systems allow the ornithopter to adapt to conditions in real time using on-board sensors and microcontrollers. YUAA will also utilize aerodynamics simulation software to optimize the mechanical design. The project will require a combination of engineering precision and creativity.

Purpose and Objectives

Ornithopters' largest weakness is that they are less efficient than traditional aircraft. However, the efficiency of ornithopter flight can be improved with active adjustment systems including dynamic control over wing power, wing deformation, and angle of attack. These active adjustments can be facilitated by on-board sensors and microcontrollers. Our main objective is to design and build an ornithopter with active adjustment systems that produce a measurable increase in flight efficiency.

To generate lift, ornithopter wings must be flexible. Therefore, there are many more degrees of freedom in ornithopter design than in traditional aircraft design; for instance, the stiffness of the wing membrane, the placement of wing spars, the flap frequency, and the flapping mechanism. The complexity of the problem lends itself well to computer modeling. Our secondary objective is to use mathematical and computer models to optimize the mechanical design of our ornithopter.

By the end of December, we will have a preliminary design verified by numerical models. The preliminary design will include tested software and CAD models for all mechanical and electrical components. By the end of the academic year, we will have a fully functional ornithopter with active adjustment systems. The ornithopter will be able to sustain flight for multiple minutes, will be controllable from the ground, and will demonstrate an improved flight efficiency when the active-adjustment systems are turned on.

Methodology

The ornithopter will use a modular design to allow for rapid prototyping and testing. The wings will be constructed out of ripstop nylon or duralar embedded with carbon fiber spars. One carbon fiber spar will run along the front edge of the wing while thinner, more flexible carbon fiber spars will provide structure for the rest of the wing. The precise shape of the wings and arrangement of the s pars will be optimized during the design process.

The wings will attach to high-torque servos which snap into a custom carbon fiber frame. This approach is different from the majority of ornithopters, which use a gear box to control the wings. The servo approach will allow us to control the wings independently and give us t he more precise control necessary for active adjustments. The frame will also include a slot for a custom PCB which manages connections between an RC receiver, a miniature microcontroller, and a gyroscope.

Data from the gyroscope will be processed by the microcontroller and used to make real-time adjustments t o the angle of attack and flapping cycle. For example, when the gyroscope detects that the pitch of the ornithopter is rapidly increasing, the wings will rotate in order to stay below the critical angle of attack. An RC controller will allow us to communicate with the ornithopter in order to steer and alternate between different behaviors such as flapping, gliding, and diving.

Feasibility and Timeline

The project will be completed by the end of the academic year. YUAA has completed an ornithopter project two years ago, suggesting that the current ornithopter project is feasible. However, our ornithopter will be significantly different from the previous ornithopter. First, we will be using servos to control the wings instead of a gear box. This will significantly simplify the mechanical design, giving us more resources to focus on optimizing efficiency and implementing active adjustment systems, which the previous ornithopter did not include.

The first semester of the project will involve learning the principles of ornithopter flight, developing numerical models, creating software for the active adjustment systems, and optimizing our design. These tasks are all feasible within the current restrictions imposed by the pandemic. In the second semester of the project, we will begin a rapid prototyping and testing phase in which we go through many iterations of the ornithopter. We will build a testing rig to quickly evaluate the thrust and lift generated by each ornithopter iteration. By the end of the academic year, we will test our final ornithopter with and without the active-adjustment systems to determine the improvement in efficiency.

Project Participants and Outside Resources

The project currently has seven participants from a variety of majors. Although the project is entirely student run, our official faculty advisor is Professor Larry Wilen. Depending on access to the CEID in the spring, the project will use many of the resources available in the CEID, including jumper cables, screws, soldering equipment, 3D printers, and laser cutting. If access to the CEID is restricted in the spring, the project will outsource some fabrication tasks such as the fabrication of the carbon fiber frame. In addition to applying for funding from YSEA, we are also applying for $1000 from the CT Space Grant and we will receive some funding from YUAA.

Participant	Class Year	Anticipated Major

[Participant names are omitted for purposes of anonymity]

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Itemized Budget

Item	**Cost**	**Total Cost**
Rubber-band Powered Ornithopters	$400	$400
Arduino Starter Kits	$200	$600
Ripstop Nylon	$100	$700
Custom Carbon Fiber Frame	$400	$1100
Carbon Fiber Wing S pars	$100	$1200
High-torque Servos	$400	$1600
Teensy	$50	$1650
RC Controller	$100	$1750
Gyroscope	$100	$1850
Testing Rig	$200	$2050
LiPo Batteries	$50	$2100
Custom PCB	$100	$2200
Shipping	$100	$2300