FLAPPING WING MICRO AIR VEHICLE (FWMAV)

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Introduction

In recent history, humans have discovered and constructed the mechanisms of flight. As far as technologies have advanced, flying birds and insects still outperform the agility, maneuverability, and stability of human-made aircrafts. The research of flapping wing micro air vehicles (FWMAV) studies the phenomenon behind the flapping wing and examine ways to design similarly efficient flight mechanism

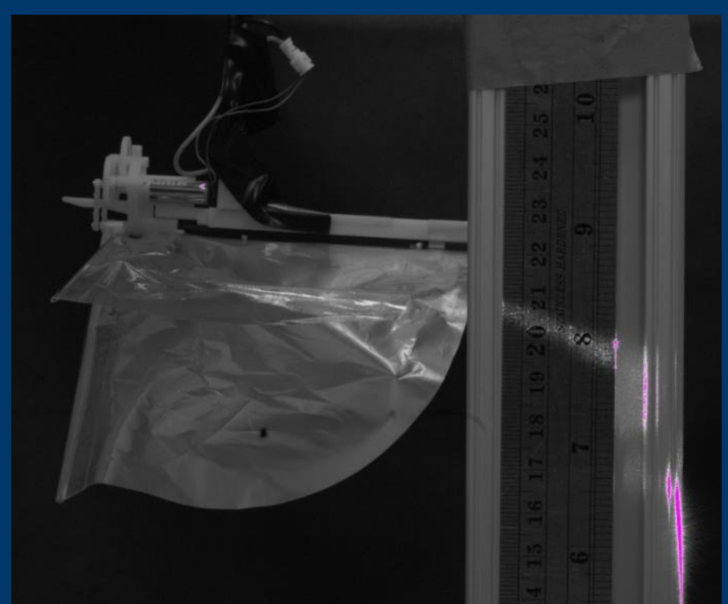

Figure. 1: Experimental setup for FWMAV flow visualization

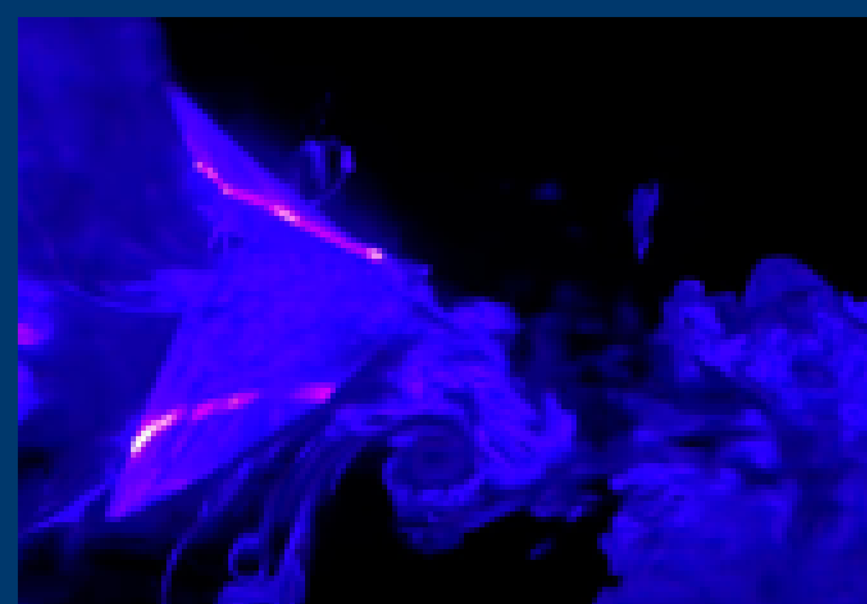

Figure. 2: Visualization of the flow field around FWMAV

Goals & Objectives

FWMAV utilizes unsteady aerodynamics and nonlinear flight mechanism to achieve its aerial capabilities. To identify and attempt to understand the physical aspects of FWMAVs, three main components are evaluated; the non-linear flight mechanism, the flow field, and the force generated. The goal is to design, experiment, and combine all the data and extrapolate quantifiable results and illustrate the high performance of FWMAV.

Figure. 3: PIV capture setup

Figure. 4: PIV capture of flow field around FWMAV

Particle Image Velocimetry (PIV)

PIV combines an air particle seeder, a synchronizer, a high-power laser, and a high-speed camera alongside capture software to trace individual air particle flow and eventually quantify the velocity vectors of the flow field around the aircraft.

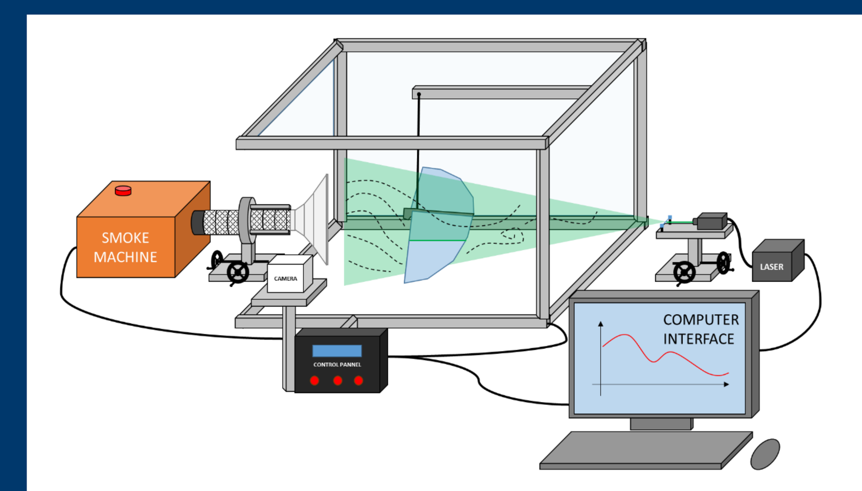

Figure. 5: Schematic of the flow visualization setup

Figure. 6: PIV setup with phase-lock laser setup

Load Cell

The forces generated by the aircraft are measured by a two-axis load cell system with strain gauges. The thrust and lift data was collected at various frequencies.

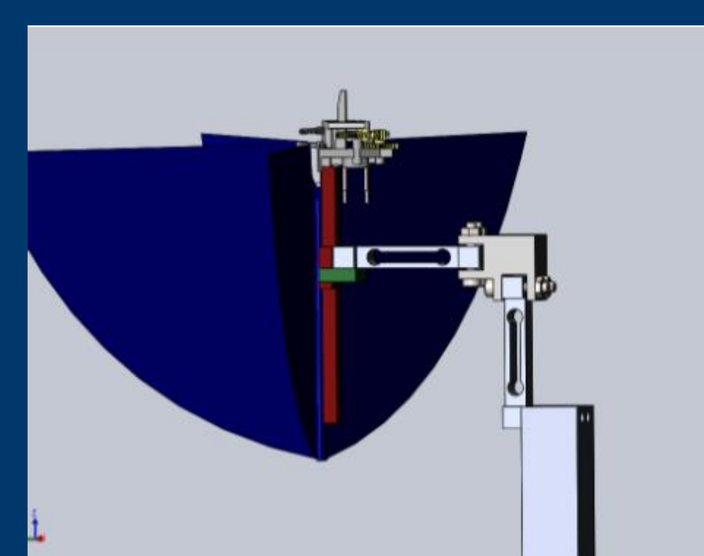

Figure. 7: Two-axis strain gauge load cell to collect thrust and lift data

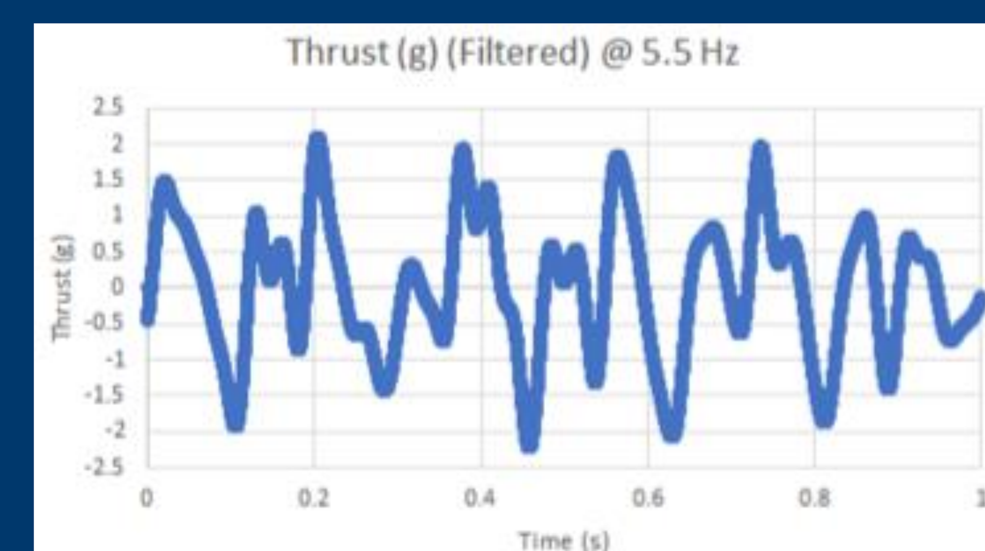

Figure. 8: Thrust at 5.5 Hz flapping rate with noise filter

3D Motion Capture

Ansys simulation and 3D motion capture are utilized to visualize and quantify the contributions of the wings to flight.

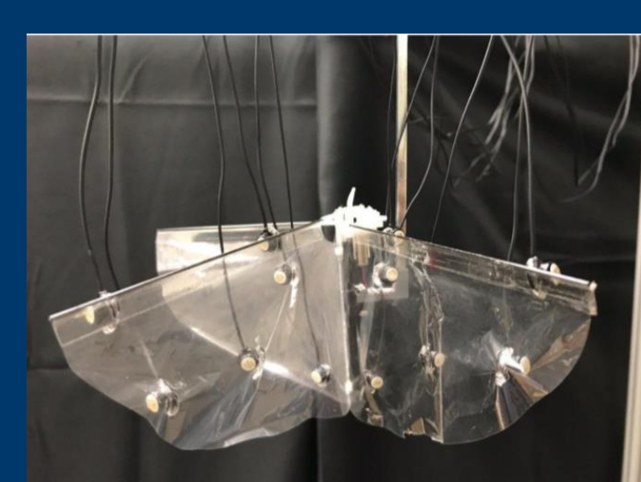

Figure. 9: 3D Motion Capture LED trackers on the wings

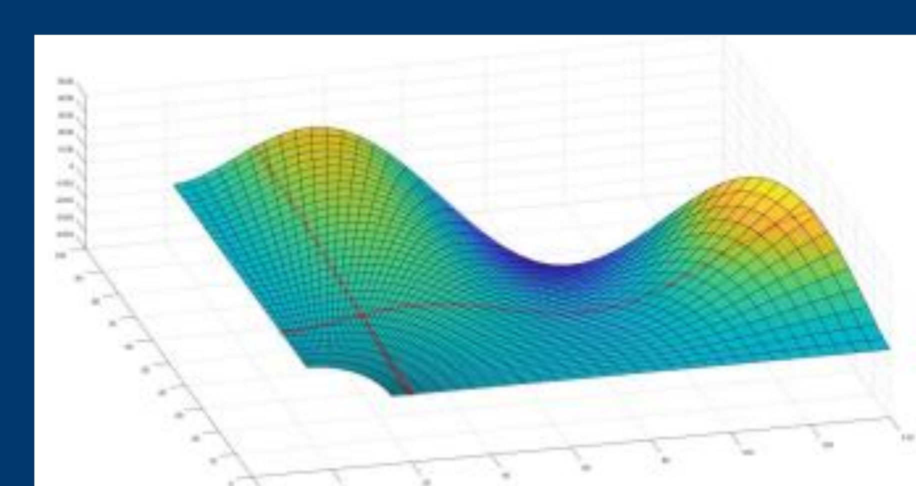

Figure. 10: Ansys simulation of the mode shapes of the aircraft

Results

Confirmed existence of "clap and fling" effect that generates an extra burst of thrust. Discovered that certain wing configurations produced more lift than others. The flexibility of the wings may help generate thrust and lift. Certain frequencies enabled maximum aircraft stability, although the results vary according to the properties and design of the aircraft.

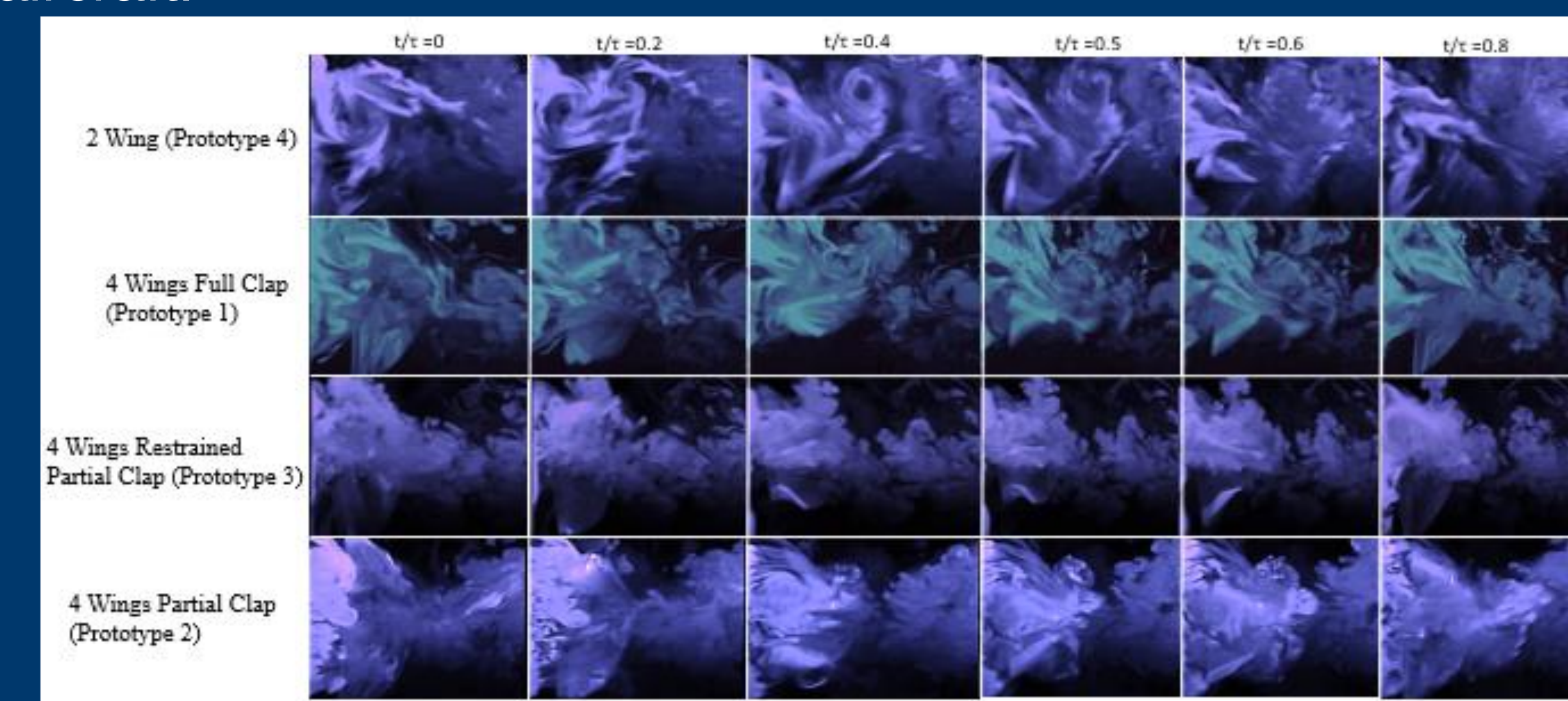

Figure. 11: Flow visualization comparison of different configuration of the wings at 75% if the wingspan

Conclusion & Application

More work is needed with PIV and 3D motion to examine more details of the flow field and flight mechanism. Other than the value of research and discovery, the ability to quickly switch between different flight modes, and the ability to hover makes FWMAV versatile in its applications.

Figure. 12: FWMAV Quadcopter - "Quadflapper"

Figure. 13: FWMAV Small Quadcopter - "Tinyflapper"

References:

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[2] Taha, H. E., Kiani, M., and Navarro, J., Experimental Demonstration of the Vibrational Stabilization Phenomenon in Bio-inspired Flying Robots, IEEE Robotics and Automation Letters. Vol 3, No. 2, 2018, pp. 643-647.

[3] Taha, H., Hajj, M. and Beran, P., 2014. State-space representation of the unsteady aerodynamics of flapping flight. *Aerospace Science and Technology*, 34, pp.1-11.