Drone Fluid Dynamics

Qualitative Analysis of High-Velocity Fluid Packets

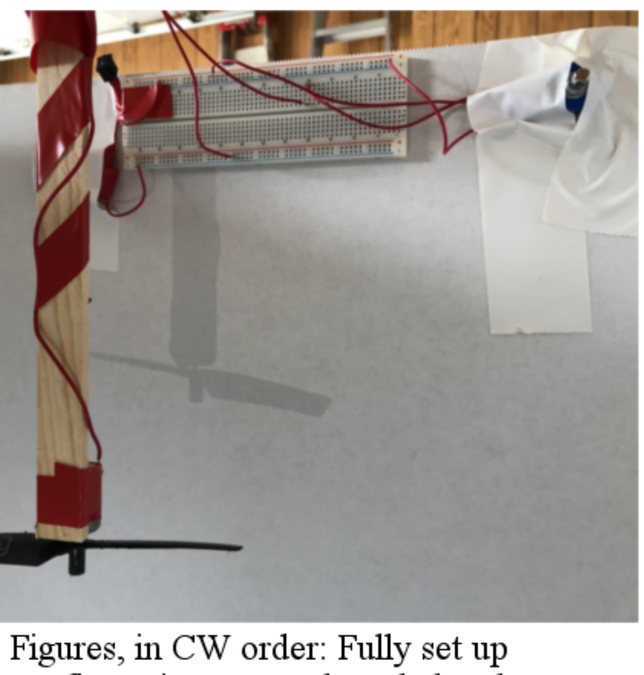
Alexander Thill, May 2020

Introduction

Computational analysis of airflow through and around drone propellers is an emerging field, but some work done already shows the potential for improving drone design using CFD.
The object of my own research was to illustrate these pockets of high velocity, where they are created, where they move, and how they originate and dissipate through physical means. I attempted to do this for a single propeller, as I did not have access to a multi-rotor UAV.

Methodology

I acquired multiple propellers, two DC motors, a precision potentiometer, and the batteries and wiring necessary to create a simple circuit. This circuit allowed me to control the power supply to the DC motor and the attached propeller.
Two poster boards were used to create a chamber for the smoke to enter and be captured on my phone's camera, which was placed on the side of the chamber opposite the wiring. The PVC piping in contains a smoke bomb from which smoke was concentrated and directed at the propeller.



Figures, in CW order: Fully set up configuration, poster board chamber, curcuit/porpeller setup, dissembled PVC apparatus

Results

The video from the final run produced stills which demonstrated the propagation of high-velocity packets of air underneath the propeller. However, I also noticed the packets were not positioned directly below the end of the propeller with an inward curve, as expected, but rather found them inside the propeller ends, with mostly straight-down distribution.
The below images are stills from the slow-motion video of smoke flow through the moving propeller.
The pink circles indicate the high-velocity packets.

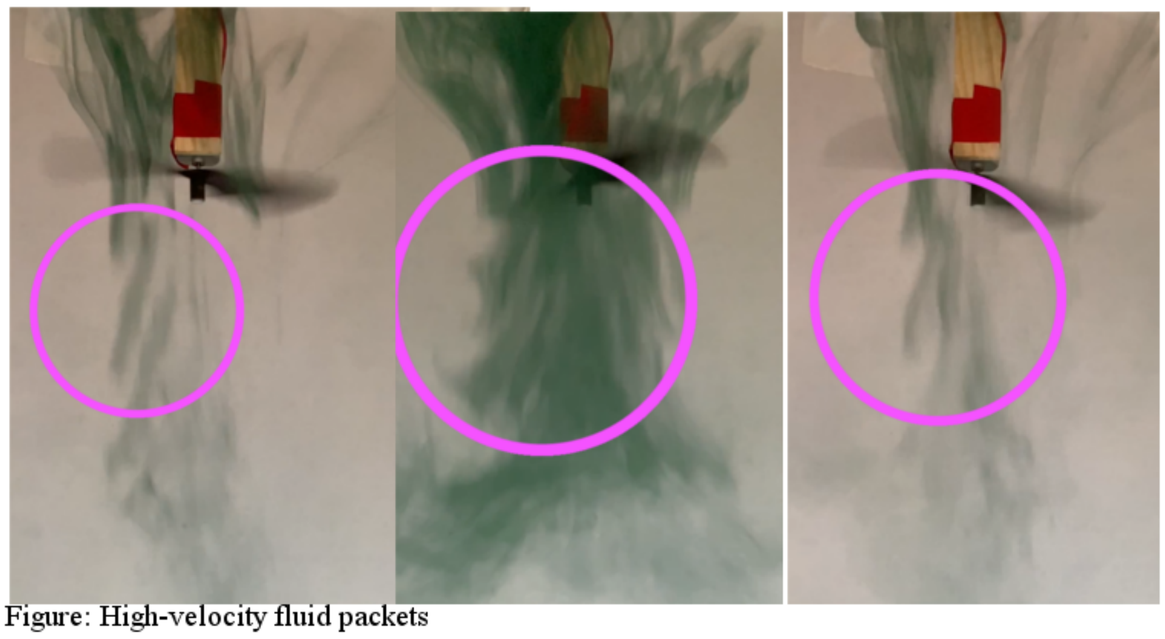
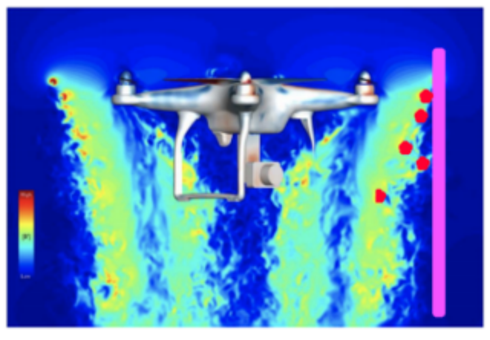


Figure: High-velocity fluid packets

Conclusion and Discussion

Key Conclusions:

1. The high-velocity packets of fluid observed in the Schlieren setup and the NASA study can be found with different propellers, regardless of airfoil design.
2. Airfoil design may be vital in defining the shape, frequency, and spatial propagation of these high-speed fluid packets.
3. The observations of flow through a propeller possible with high-speed cameras can be augmented with techniques like the Schlieren mirror setup, but may not be necessary for basic visual representations, e.g. using visual smoke rather than observing heat gradients.



(a) DJI Phantom 3 complete.

Figure: Comparison of results to 2018 NASA CFD Analysis (cited below)

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NASA, 2018. High-Fidelity Computational Aerodynamics Of Multi-Rotor Unmanned Aerial Vehicles. AIAA SciTech Forum 2018. [online] Kissimmee, FL, USA: NASA.