

# Drag Model Identification and Wind Prediction with “Off-The-Shelf” Drones

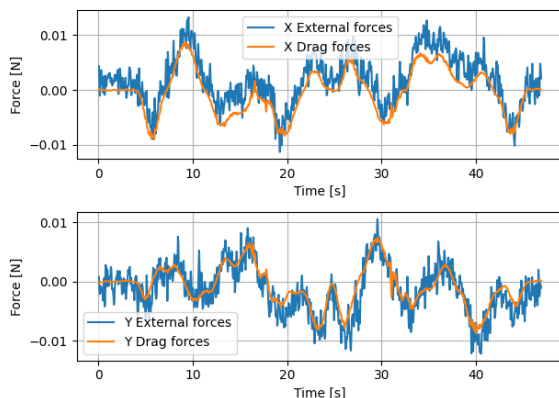
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The increasing application of rotary-wing Micro Aerial Vehicles (MAVs) in environmental monitoring highlights the need for compact and lightweight methods for measuring wind conditions. This project addresses this requirement by implementing and evaluating a lumped drag model capable of predicting wind speed and direction solely from onboard sensor data of the Crazyflie 2.1 drone, therefore eliminating the need for specialized wind measurement sensors.

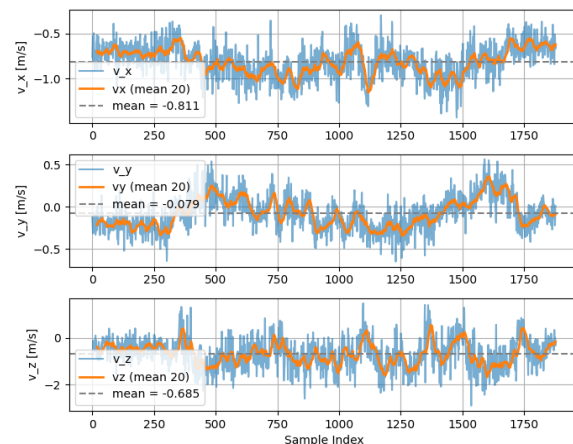
Wind estimation using a lumped drag model is based on the assumption that, under wind-free flight conditions, the external forces acting on the drone are solely due to aerodynamic drag. By identifying the parameters of the drag model from onboard measurements, the airspeed of the drone can be computed by inverting the identified model. Subsequently, the wind velocity is inferred using the wind triangle relationship between the drone's measured ground speed and its computed airspeed.

Drag model parameters were systematically identified through experimental flights conducted under wind-free conditions. Two distinct identification processes were undertaken: one for vertical motion to estimate drag and thrust-related parameters, and another for horizontal parameters. Special care was taken to excite a wide range of dynamic states through various trajectory patterns, including vertical, horizontal, and mixed flights designed using minimum-jerk and Lissajous curves.



Comparison between estimated and measured horizontal forces

Validation tests were performed in a wind tunnel with known wind speeds, confirming the model's capability to reliably estimate wind direction and magnitude from onboard sensor data. A notable challenge during validation was the model's sensitivity to variations in the drone's mass, primarily caused by battery changes between flights. To address this, a method to estimate the drone's effective mass during hover using tilt angle measurements was developed, thus reducing estimation inaccuracies.



Wind vector estimation

Results demonstrated the effectiveness of the proposed model, particularly in estimating horizontal wind components and accurately capturing wind direction. Vertical component estimation proved more challenging, highlighting the model's susceptibility to errors induced by small mass fluctuations. The project successfully demonstrated that the Crazyflie drone, with proper modeling and calibration, can provide reliable wind estimates.

Recommendations for future works include refining the real-time estimation of drone mass and implementing the developed wind estimation pipeline for real-world applications beyond controlled laboratory conditions.