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A Sensor Fusion Approach for Accurate Wind Estimation and System Characterization

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Accurately estimating wind speed conditions at different operational heights is crucial for assessing a kite's flight state and controlling its trajectory effectively. Currently, wind measurements are typically taken at ground level and extrapolated to the kite's flying height. However, this approach overlooks atmospheric wind gradient and veer, leading to errors.

An alternative approach involves the installation of airborne flow sensors, specifically pitot tubes and wind vanes, to capture the apparent velocity vector, from which wind velocity can be calculated [1]. Nonetheless, substantial inaccuracies can occur, particularly if the pitot tube is significantly misaligned with the apparent velocity. The challenge becomes more pronounced in the case of soft-wing kites, where the entire structure is deformable, further contributing to potential inaccuracies.

To address this problem, the present study explores a sensor fusion approach. This technique combines real-time measurements with a detailed model of the system [2], incorporating factors like the tether's elasticity and the weight and inertia of the kite control unit, combined with an Extended Kalman Filter (EKF) to precisely determine the wind conditions at the kite's flying height. This integrated approach aims to provide a more accurate and reliable estimation of wind parameters, mitigating the limitations associated with traditional methods and enhancing the overall control and trajectory optimization of kites during flight.

Furthermore, this methodology also enables a comprehensive characterization of the entire flight state of the system, including aerodynamic coefficients and tether sagging. These insights can be harnessed for various purposes, such as system identification and the validation of numerical models pertaining to the system. In essence, it offers a more holistic understanding of the system's performance and behavior.

Moreover, the versatile nature of the EKF permits the integration of various sensor setups. This adaptability is particularly valuable in determining the minimal sensor configuration required for accurate wind condition estimation.

As part of the Meridional project [3], several experimental campaigns will be executed, including measurement campaigns from LiDAR and drone-based systems. These campaigns will allow for the validation of the described analysis tool and the identification of the most effective sensor arrangement, which can rely solely on kite position, speed, and tether force.

References:

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