Paper Title: Aerodynamics-Aware Design and Analysis of Controllers for Tailsitter Vehicles

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Abstract

Tailsitter transitioning unmanned aerial systems (t-UAS) are vehicles that, through rigid body rotation, are capable of operating in both vertical take-off and landing (VTOL) and fixed-wing flight regimes. The typical approach for control design for tailsitter t-UAS considers the aerodynamics of the wings as a disturbance to either be avoided or compensated for, specifically during the pure VTOL and transition flight regimes. This can result in overly conservative controllers or otherwise degraded tracking performance. To address this, we present a unified design and analysis approach for a controller that explicitly accounts for the effect of wing aerodynamics for tailsitter t-UAS operating in the transition flight regime. The overall control architecture uses feedback linearization with nested control loops, with position controlled in the outer loop and attitude controlled in the inner loop. The outer loop uses feedforward knowledge of the aerodynamic forces from the mission planning stage, while the inner loop is designed assuming that moments generated by the aerodynamic forces are negligible. We derive analytical conditions that guarantee stability of the outer and inner loop controllers in the presence of bounded uncertainty in the aerodynamic forces and moments. We then provide performance bounds for both the outer and inner loop in the presence of these unmodeled or uncertain aerodynamic forces and moments. Finally, we use a high-fidelity simulation of a quadrotor biplane tailsitter to illustrate the stability result and quantify controller performance statistically.