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Predictive Control of a Morphing Airborne Wind Energy System

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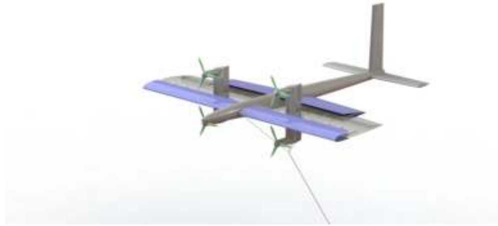
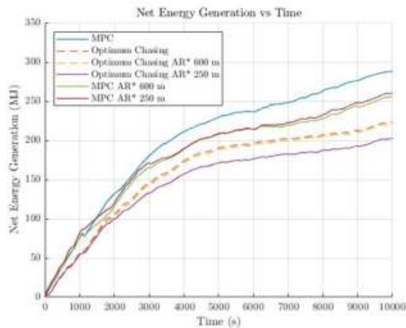
In this work, we have assessed a predictive control approach for an energy-harvesting kite capable of adjusting its geometric parameters in real time. The variable nature of the wind shear profile motivates control strategies that allow for variable-altitude operation, which in turn requires a variable tether length for a given elevation angle. As the tether length increases, however, the contribution of kite drag to the total drag decreases. When tether drag dominates, it is beneficial to deploy a kite with maximal wing area, irrespective of efficiency; however, when the tether length and drag are minimal, wing efficiency is key. This coupling between tether length and the optimal lift-drag characteristics motivates the development of control strategies for real-time wing morphing.

In this work, aspect ratio was considered as a controllable, reconfigurable plant parameter with a fixed-span wing. A two-layer model predictive controller was developed, where the first layer determines the tether length, elevation angle, and aspect ratio setpoints that maximize energy generation assuming an infinite time horizon with spatially omniscient knowledge of the flow field. The second layer finds the rates that will maximize energy generation and bring the kite to these setpoints over the horizon. Preliminary simulations using a simplified plant modeled from fundamental equations in [1] has shown upwards of an 11% increase in energy generation, as compared to a fixed-wing kite following the same control strategy. Furthermore, the MPC formulation showed a 25% increase in energy generation when benchmarked against a naive "optimum chasing" controller that adjusts the reconfigurable parameters without regard to the time or energy costs associated with doing so.





Top: *CAD model of morphing kite. Telescoping flaps and slats deploy along the leading and trailing edge to augment the wing area.* ***Bottom:*** *Projected energy generation for morphing kites with MPC and naive "optimum chasing" controllers benchmarked with fixed aspect ratio kites optimized for 250m and 600m operation.*

References:

[1] Loyd, M. L.: Crosswind Kite Power. Journal of Energy ***4****(3), 106-111 (1980)*