Pterodactyl: Control Architectures Development for Integrated Control Design of a Mechanically Deployed Entry Vehicle

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Abstract

The need to return high mass payloads is driving the development of a new class of vehicles, Deployable Entry Vehicles (DEV) for which feasible and optimized control architectures have not been developed. The Pterodactyl project, seeks to advance the current state-of-the-art for entry vehicles by developing a design, test, and build capability for DEVs that can be applied to various entry vehicle configurations. This paper details the efforts on the NASA-funded Pterodactyl project to investigate multiple control techniques for the Lifting Nano-ADEPT (LNA) DEV. We design and implement multiple control architectures on the LNA and evaluate their performance in achieving varying guidance commands during entry.

First we present an overview of DEVs and the Lifting Nano-ADEPT (LNA), along with the physical LNA configuration that influences the different control designs. Existing state-of-the-art for entry vehicle control is primarily propulsive as reaction control systems (RCS) are widely employed. In this work, we analyze the feasibility of using both propulsive control systems such as RCS to generate moments, and non-propulsive control systems such as aerodynamic control surfaces and internal moving mass actuations to shift the LNA center of gravity and generate moments. For these diverse control systems, we design different multi-input multi-output (MIMO) state-feedback integral controllers based on linear quadratic regulator (LQR) optimal control methods. The control variables calculated by the controllers vary, depending on the control system being utilized and the outputs to track for the controller are either the (i) bank angle or the (ii) angle of attack and sideslip angle as determined by the desired guidance trajectory. The LQR control design technique allows the relative allocation of the control variables through the choice of the weighting matrices in the cost index. Thus, it is easy to (i) specify which and how much of a control variable to use, and (ii) utilize one control design for different control architectures by simply modifying the choice of the weighting matrices.

By providing a comparative analysis of multiple control systems, configurations, and performance, this paper and the Pterodactyl project as a whole will help entry vehicle system designers and control systems engineers determine suitable control architectures for integration with DEVs and other entry vehicle types.

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