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Robust Nonlinear Control Theory with Applications to Aerospace Vehicles

AASERT Grant

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This grant is a subcontract to the University of Minnesota, under the supervision of Prof. Gary Balas. This AASERT subcontract augments the parent subcontract to UMN and is focused on the application of Linear Parameter Varying Control to Aerospace Systems.

Recent results by Packard have shown that a continuously changing controller which depend on a measured variables, e.g. Mach number, dynamic pressure, angle-of-attack, can be directly synthesized which guarantee a given level of performance and stability for the entire set of linearized plant models. To understand these results, consider describing all the equilibrium points in the flight regime by a linear, state space system which is a function of key variables Mach number, dynamic pressure, and angle-of-attack. This set of linearizations has a polynomial dependence on the key variables which can be written as a linear fractional transformation (LFT) on these variables. The control problem is formulated with this parametrization of all the possible equilibrium points. The resulting controller is a continuously scheduled controller, scheduling as a function of the same measured variables describing the linearizations, which minimizes the scaled H_∞ norm. This continuously gain-scheduled controller has guaranteed performance and stability levels for all the equilibrium points. This is in sharp contrast to classical gain-scheduling which provides no performance or stability guarantees at non-design equilibrium points. More recent results allow the inclusion of rate bounds on the time variation of the scheduled variables further reducing the conservativeness of these designs. The synthesis of gain-scheduled H_∞ feedback controllers that stabilize and achieve a desired performance objective systems with polynomial dependence on scheduled variables has been shown to be the solution of a finite-dimensional, convex feasibility problem.

The research at the University of Minnesota under the AFOSR PRET program has focused on applying linear-parameter varying (LPV) H_∞ control design methods to aerospace vehicles. We have developed heuristic approaches, similar to D-K iteration, to include performance and robustness objectives in the linear-parameter varying framework. This approach has been applied successfully to the design of controllers for the F-14 lateral-directional axis during powered approach. These controllers are designed to operate in the powered-approach flight envelope between $\alpha = 2$ degrees, 180 knots to $\alpha = 14$ degrees and 128 knots based on four linearized models at $\alpha = 2, 6, 10.5$, and 14 degrees angle-of-attack. The LPV controllers, which schedule on angle-of-attack, were implemented successfully in the full order F-14 simulation and tested in pilot-in-the-loop simulations at the Naval Air Warfare Center in Patuxent River, Maryland. We believe this is the "first" pilot testing of controllers designed using LPV control design techniques.

Future work will include continued application of these results to flight control systems as well as other systems.