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Robust Nonlinear Control Theory with Applications to Aerospace Vehicles

AASERT Grant

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FINAL REPORT
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1 Background and Objectives

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

The focus of our PRET program is fundamental research in general methods of analysis and design of complex uncertain nonlinear systems. We are working to create new mathematical theory as well as doing the necessary work to make that theory help engineers solve a variety of real industrial problems. Caltech's Control and Dynamical Systems department (CITCDS) was created with precisely this goal, and our industrial collaborators, led by Honeywell, give us a proven team. The University of Minnesota contributes valuable application and experimental expertise, and an academic team member geographically co-located with Honeywell, facilitating personnel exchange.

The main tasks that were to be addressed under this program were:

1. Improved numerical algorithms and the development of software for solving the convex feasibility problem.
2. Clearer understanding of the limitations and conservatism using these techniques.
3. Application of the H_∞ gain-scheduling techniques to a wide variety of problems including flight control, missile autopilots, process control and vibration suppression.
4. Development of an efficient, user-interface to help control engineers transform real-world nonlinear control problems into the gain-scheduled framework.
5. Implementation issues, including experimental verification and real-time control implementation of these gain-scheduled control algorithms.

The ultimate goal of the research is to make these methods applicable to a wide class of realistic engineering systems, and easily accessible to control engineers.

2 Accomplishments

This worked performed under this grant focused on application of applying linear-parameter varying (LPV) H_∞ control design methods to the problem of control of flutter. We have developed heuristic approaches, similar to D-K iteration, to include performance and robustness objectives in the linear-parameter varying framework

A gain-scheduled, LPV controller for active flutter suppression of the NASA Langley Research Center's Benchmark Active Controls Technology wing section was designed. The wing section changes significantly as a function of Mach and dynamic pressure and is modeled as a linear system whose parameters depend in a linear fractional manner on Mach and dynamic pressure. The resulting gain-scheduled controller also depends in a linear fractional manner on Mach and dynamic pressure. Closed-loop stability is demonstrated via time simulations in which both Mach and dynamic pressure are allowed to vary in the presence of input disturbances. The linear fractional gain-scheduled controller and an optimized linear controller (designed for comparison) both achieve closed-loop stability, but the gain-scheduled controller outperforms the linear controller throughout the operating region. For comparison, an LPV controller based only on the linearized data, and not the LFT model of the flutter data, was also synthesized. The LPV controller outperformed the LFT-based gain-scheduled design and led to improved performance and robustness through out the flight envelope.

The results of this research were documented in two journal articles and a conference paper.

3 Personnel Supported

Jeff Barker, UMN graduate student.

4 Publications

1. J.S. Vipperman, J.M. Barker, R. Clark, and G.J. Balas, "Comparison of μ and $\mathcal{H}_2$-synthesized controllers on an experimental typical section," *AIAA Journal of Guidance, Dynamics and Control* , vol. 22, no. 2, March-April, 1999, pp. 278-285.

2. J.M. Barker, G.J. Balas, and P.A Blue, 'Gain-scheduled linear fractional control for active flutter suppression," *1999 American Control Conference*, San Diego, CA, June, 1999.

3. J. Barker and G.J. Balas, "Comparing linear parameter-varying gain-scheduled control techniques for active flutter suppression," submitted to *AIAA Journal of Guidance, Dynamics and Control*, May, 1999.