NASA-CR-195826

IN-63-CR
8438
8P

1993 - 94 SEMIANNUAL STATUS REPORT FOR NASA Grant NAG 5-2109

Parametric Robust Control and System Identification: Unified Approach

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Submitted to
NASA Goddard Space Flight Center
Greenbelt, MD 20771

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Code 714.1
Robotics Branch
Engineering Directorate

Report Period: November 1, 93 - April 30, 94

May 10, 1994

(NASA-CR-195826) PARAMETRIC ROBUST CONTROL AND SYSTEM IDENTIFICATION: UNIFIED APPROACH Semiannual Status Report, 1 Nov. 1993 - 30 Apr. 1994 (Tennessee State Univ.) 8 p

N94-32980

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G3/63 0008438

Progress of Research

This semi-annual report briefly summaries the research activities covering the period of November 1, 1993 to April 30, 1994.

Robust Controller Synthesis via H_∞ Methods

Despite significant advancement in the area of robust parametric control, the problem of synthesizing such a controller is still a wide open problem. Thus, we attempt to give a solution to this important problem. Our approach captures the parametric uncertainty as a H_∞ (unstructured) uncertainty so that H_∞ synthesis techniques are applicable. These simple techniques are reported in *1993 IEEE Conference on Decision and Control.* Although the techniques cannot cope with the exact parametric uncertainty, they give a reasonable guideline to model the unstructured uncertainty that contains the parametric uncertainty. An additional loop shaping technique is also introduced to relax its conservatism.

Truss Structure Experiments: Modeling and Control

In this experiment, we built the 10 bay T-shape aluminum truss structure as shown in Figure 1 Each bay of the structure is a 0.5 meter cube made of hollow alu-

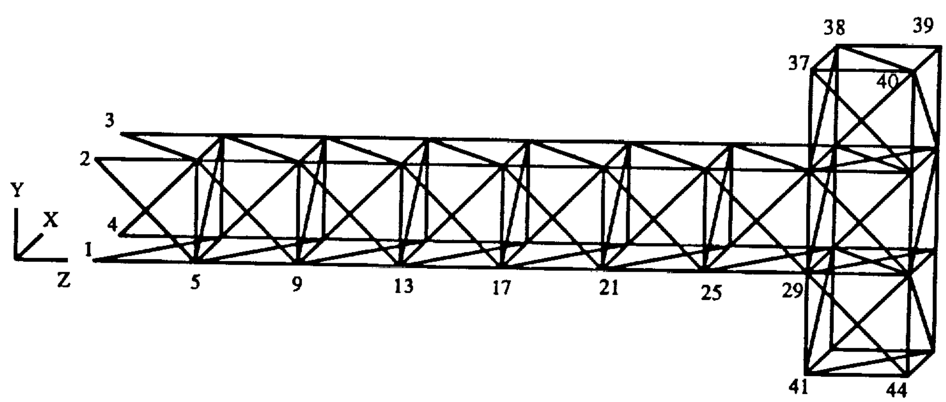

Figure 1: Finite Element Model of 10 Bay Truss with Node Number

minum tubing joined at spherical nodes with threaded fasteners. The final structure has a mass of 31.5 kg and is cantilevered horizontally from a massive monolithic base. We select nodes 17 and 44 to add uncertainties (mass). We used a reaction mass actuator to suppress the vibration due to a random excitation. The objective of this experiment is to obtain an interval transfer function model that captures a family of systems that represent the structure with added mass ranging from 0 to 2.5 kg and to achieve vibration suppression over this family of systems. The identification part of this experiment is reported in *1994 AIAA/ASME Adaptive Structures Forum*, and the extended manuscript is being prepared for a journal publication.

Textbook Preparation

Currently, the principal investigator is coauthoring (with S.P. Bhattacharyya and H. Chapellat) a textbook titled *Robust Control: The Parametric Approach* which will be published by Prentice-Hall Publishing Company. This textbook not only contains the last 15 years of development on the subject of parametric robust control but also gives the essential concepts, motivation, and background of linear control. We hope the book will well serve students and researchers as well as engineers in practice. The book is now in the final stage, and we expect to submit the final manuscript to the publisher shortly.

Experiment Setup

Currently two of our undergraduate students are involved in building two experiments: a fixed flexible arm and a flexible slewing beam. Through these experimental setups, our undergraduate students will practice their textbook knowledge on dynamics and controls in real world physical systems. Once the experiments are built, we will initiate various robust control and identification experiments to examine practical problems and to validate the theoretical developments.

Abstracts of Publications Supported by NAG 5-2109

November 1, 93 - April 30, 94 Period

Comments on
"Extreme Point Results for Robust Stabilization
of Interval Plants with First Order Compensators"[1]

S.P. Bhattacharyya and L.H. Keel

Abstract

In this note we point out that the main result (Theorem 1) of the above paper [1] follows immediately on applying the vertex result of Hollot and Yang [2] to the generalization of Kharitonov's Theorem given by Chapellat and Bhattacharyya [3]. We also point out that more general vertex results are known [4,5].

REFERENCES

[1] B. R. Barmish, C. V. Hollot, F. J. Kraus, and R. Tempo, "Extreme point results for robust stabilization of interval plants with first order compensators," *IEEE Transactions on Automatic Control*, vol. 37, pp. 707 – 714, June 1992.

[2] C. V. Hollot and F. Yang, "Robust stabilization of interval plants using lead or lag compensators," *Systems and Control Letters*, vol. 14, pp. 9 – 12, 1990.

[3] H. Chapellat and S. P. Bhattacharyya, "A generalization of Kharitonov's theorem: robust stability of interval plants," *IEEE Transactions on Automatic Control*, vol. AC - 34, pp. 306 – 311, March 1989.

[4] S. P. Bhattacharyya, "Robust parametric stability: the role of the CB segments," in *Control of Uncertain Dynamic Systems*, (S. P. Bhattacharyya and L. H. Keel, eds.), Littleton, MA: CRC Press, September 1991.

[5] S. P. Bhattacharyya, "Vertex results in robust stability," Tech. Rep., TCSP Report, Texas A&M University, April 1991.

[1]IEEE Transactions on Automatic Control, Vol. 38, No. 11, pp. 1734 - 1735, November, 1994

Robust Stabilization of Interval Plants Using
H-infinity Methods[2]

S. Bhattachrya, L.H. Keel, and S.P. Bhattacharyya

Abstract

This paper deals with the synthesis of robustly stabilizing compensators for interval plants whose parameters consist of transfer function coefficients which vary within prescribed ranges. Well-known H_∞ methods are used to establish robust stabilizability conditions for a family of plants and also to synthesize controllers that would stabilize the whole family. Though it is somewhat conservative, these methods are useful and give a very simple way to come up with a family of robust stabilizers for an interval plant, to enlarge the range of parameter variations without losing robust stabilizability, and also to evaluate the worst case performance of the designed controller.

[2]Proceedings of the 1993 IEEE Conference on Decision and Control, San Antonio, Texas, December 15 - 17, 1993.

Control System Design for Parametric Uncertainty[3]

L .H. Keel and S. P. Bhattacharyya

Abstract

This paper introduces some recently developed frequency domain design techniques that are effective in the design of control systems that are required to be robust under parametric uncertainty. We have extended the well known classical control tools (i.e., Nyquist plot, Bode plot, and Nichols chart) developed for a fixed plant to the domain of *families* of plants where the uncertain parameter varies in intervals. Using this new family of plots, classical control design techniques can be used to design robust control systems. The technique is illustrated by examples.

[3]International Journal of Robust and Nonlinear Control, Vol. 4, pp. 87 - 100, January - February, 1994

Interval Model Identification for Flexible Structures with Uncertain Parameters[4]

J.-S. Lew, T.L. Link, E. Garcia, and L.H. Keel

Abstract

A novel approach is developed for modeling a structure with uncertain parameters directly from experimental data. In the recent years the study of interval control systems has been the subject of much controls and systems research. The interval model of the transfer function is the model structure chosen in this paper. The system identification algorithm proposed in this paper bridges the techniques developed in the area of interval control systems to the practical problems. A ten bay truss structure with various added masses is designed to represent a structure with uncertainties. The results of the open loop experiments of the ten bay truss structure illustrate and verify the algorithm developed.

[4]Proceedings of the 1994 AIAA/ASME Adaptive Structures Forum, April 21 - 22, Hilton Head, SC