N91-18989

1990

NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA

SYSTEM IDENTIFICATION AND CONTROLLER DESIGN USING EXPERIMENTAL FREQUENCY RESPONSE DATA

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Date: August 24, 1990

Contract: The University of Alabama
NGT 01-002-099

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Introduction

Recent findings of Guest Investigators involved in modeling and controller design for the NASA Marshall Single Structure Control Facilityhave raised questions regarding the ability of modern control design techniques and modern modeling techniques to deal effectively with the stringent modeling and control design requirements of Large Space Structure Control. In particular, these investigators have speculated that the modeling, or system identification, component of realistic control design is critical to obtaining high performance closed loop systems. This summary is a brief and general discussion of the results of investigations into the modeling and control issues performed under sponsorship of the NASA/ASEE Summer Faculty Fellowship Program.

There are several issues addressed in this report. The first is an investigation of a modeling technique based on least squares identification of individual transfer functions from measured frequency response data. The second is an investigation of multiobjective optimization techniques applied to the modeling,or system identification, problem. The third issue is an investigation into the question of whether multiobjective optimization approaches can be effectively used for control system design using only frequency response data, thereby bypassing the difficult modeling problem. The last, and most mundane, issue investigated involves the resolution of seeming discrepancies between predicted and measured control computer time delays in the Single Structure Control Facility.

System Identification from Experimental Frequency Responses

Two techniques for system identification have been investigated. The first is a least squares techniquefor estimating z-domain transfer function coefficients from frequency response data. The individual transfer functions are converted to state space form and combined to form a non-minimal multivariable state space model from which a final minimal model is extracted. The second method utilizes multiobjective optimization techniques to directly estimate a multivariable state space model from matrix frequency responses. The two techniques have been applied to actual data from the Single Structure Control Facility and yield comparable results. The reliability (in terms of the modeling criterion used) of the models in each case appears to be mainly dependent on the quality of the data. Both of the techniques require the use of frequency dependent weighting schemes. The model quality is heavily dependent on the frequency distribution of the available data and weighting schemes are partially based on distribution dependent weighting. The various data points are also weighted depending on the reliability of the frequency response data as estimated by the associated coherence functions.

Controller Design Directly from Frequency Response Data

One of the advantages of multiobjective optimization techniques is the fact that analytical models are not always required. A design using these techniques was successfully implemented in the control facility. This single loop design was non-trivial due to the extreme modal density of the structure. Closed loop improvements in damping for four modes were greater than a factor of three. Higher frequency modes were successfully gain stabilized. These objectives were accomplished using measured frequency response data only.

As far as the author is aware, this is the first successful implementation of a controller designed using a data only approach combined with multiobjective optimization techniques. Ongoing work concentrates on modernization of the single loop classical approach to include modern robustness and performance measures for multivariable systems.

Investigation of Control Computer Time Delays

Guest investigator measurements taken in October 1989 indicated the possible presence of an unmodeled .016 second delay in the control facility HP9000/Cosmec data acquisition and control system. Since the time delay estimate was based on estimates of input/output phase lags at one frequency and obtained at high data rates (10 kHz) compared to the control computer sampling and update rate (50 Hz), it was believed that the supposedly unmodeled delay could be resolved via true sampled data analysis. A sampled-data analysis was performed on a simple model of the HP9000/Cosmec. This analysis showed that the phase shift in question was not due to a system delay but to the accumulated effects of input and output anti-aliasing filters and the effects of sampling and data hold, which are inherently included in sampled-data controller design techniques.

1990 AFOSR Forum on Large Space Structures

The annual AFOSR Forum on Large Space Structures was attended on invitation of Harris Corporation personnel. Both government and industry speakers presented recent analytical and laboratory results. The most outstanding feature of the meeting was the amount of discussion devoted to the question of whether modern control techniques are up to the task of large space structure control design. Most speakers addressing the issue expressed the view that some recently developed techniques (e.g., H-infinity) are not presently suitable for realistic control design.

Summary

The work sponsored by this NASA/ASEE Summer Faculty Fellowship was mainly oriented toward developing techniques for modeling using frequency response data. The two techniques investigated were successfully used to identify models for a multivariable subsystem of the Single Structure Control Facility. Ongoing work involves using the identified models in conjunction with modern control techniques such as H-infinity to design controllers for the facility.

Another important result of the work performed during the Fellowship period was the successful design and implementation of a controller using only measured frequency response data and multiobjective optimization techniques. Future work in this area will be directed toward achieving modern performance and robustness specifications using multiobjective optimization.