AD-A071 200 BROWN UNIV PROVIDENCE R I DIV OF ENGINEERING F/G 12/1

CONTROL OF NONLINEAR SYSTEMS.(U)

JUN 79 A E PEARSON AFOSR-75-2793

UNCLASSIFIED AFOSR-TR-79-0827 NL

1 OF 1

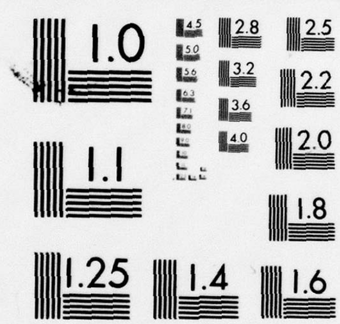
AD
A071200

END

DATE FILMED

8-79

DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFOSR-TR- 79-0827	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): CONTROL OF NONLINEAR SYSTEMS	5. TYPE OF REPORT & PERIOD COVERED: Interim
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Allan E. Pearson	8. CONTRACT OR GRANT NUMBER(s): AFOSR-75-2793
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Division of Engineering, Brown University, Providence, Rhode Island 02912	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 61102F 2304/A1
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Office of Scientific Research/NM, Bolling AFB, Washington, D.C. 20332	12. REPORT DATE: 5 June 1979
	13. NUMBER OF PAGES: 5
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Interim Progress rept. no. 4, 1 Oct 78 - 31 May 79	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

LEVEL

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DDC
RECEIVED
JUL 16 1979
C

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Control Systems, Missile Intercept Guidance and Control, Feedback Stabilization Time Varying Systems, Nonlinear Systems, System Identification, Signal Estimation.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Progress is described on a method for stablizing linear differential systems by state variable feedback in which the gain matrix stems from the finite pure integration of the controllability Gramian and the resulting system tolerates a large class of nonlinearities in the loop without destroying stability. Research results are summarized for the theoretical investigation of minimum energy controls for a class of commutative bilinear systems which relate to a two-dimensional intercept control problem. Progress and research results are also described for a new equation error formulation for the (continued) next page

DDC FILE COPY

AD A071200

DD FORM 1 JAN 73 1473

065 310

UNCLASSIFIED

Unclassified

20 Abstract (continued)

least squares parameter estimation problem for nonlinear system identification and signal reconstruction.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Progress Report No. 4

for

CONTROL OF NONLINEAR SYSTEMS

Directorate of Mathematical and Information Sciences
Department of the Air Force
Air Force Office of Scientific Research (AFSC)
AFOSR/NM, Building 410
Bolling Air Force Base
Washington, DC 20332

Grant: AFOSR-75-2793

Period Covered: October 1, 1978 to May 31, 1979

Brown University
Division of Engineering
Providence, Rhode Island 02912

PRINCIPAL INVESTIGATOR: Allan E. Pearson

June 5, 1979

I. INTRODUCTION

This progress report covers an eight month period preceding May 31, 1979, and is the fourth such progress report filed under Grant AFOSR-75-2793. The personnel listed below received at least partial support from the grant during this period. Completed and continuing research is discussed in Section III.

II. SUPPORTED PERSONNEL

J. M. Mocenigo, Research Assistant

A. E. Pearson, Professor of Engineering

K. B. Yu, Research Assistant

III. RESEARCH COMPLETED AND CONTINUING RESEARCH

The published papers which have appeared during this eight month period are listed chronologically in Section IV. Reference [1] contains a new method for stabilizing linear time varying differential systems by state variable feedback. It is related to our earlier work in this area (esp. "A Modified Quadratic Cost Problem and Feedback Stabilization of a Linear System," by W. H. Kwon and A. E. Pearson, IEEE Trans. on Auto. Contr., vol. AC-22, No. 5, pp. 838-842, October 1977) in that the feedback gain matrix is obtained by the pure integration over a finite interval of the gain matrix used in our earlier work. The resulting feedback system has the interesting property that it tolerates a larger class of nonlinearities in the loop than that permitted by other known methods (e.g. linear optimal quadratic control processes). Also, in the case of time invariant systems the controller can be designed to achieve a phase margin approaching +90°, while maintaining essentially infinite gain margin. At the present time, we are investigating the application of this class of feedback control laws (i.e. those stemming from the inverse of the controllability Gramian) to a class of linear differential-difference systems.

Reference [2] contains theoretical results of our investigations into minimum energy controllers for a class of commutative bilinear systems. This work was motivated by our earlier research on constructing a feedback control law for a two-dimensional intercept system. (Reported in "Control Law for an Intercept System," by K. C. Wei and A. E. Pearson, AIAA J. on Guidance and Control, vol. 1, No. 5, pp. 298-304, September 1978.) Some additional research has recently been carried out on certain stochastic aspects of this problem in the M.Sc. Thesis of Kai-bor Yu (listed in Section VI of this report). Work will continue in this area.

Reference [3] contains the basic theory connected with our research into parameter identification of nonlinear systems with modal type disturbances affecting the system over a finite time interval. Various elaborations and applications will appear in the near future and are under continuing development (listed in Section V of this report). One interesting recent development has been the discovery that the disturbance parameters can be eliminated from the equation error functional, leaving only the system parameters to be found by a suitable hill climbing technique. At the present time we are investigating additional computational aspects of the formulation and the application of the technique to the least squares estimation of parameters in differential-delay systems with unknown time lag. Some additional work is also being carried out on the signal reconstruction aspect of the formulation, the basic theory of which will be presented at the 1979 JACC (listed in Section V).

IV. REFERENCED PUBLICATIONS

[1] Kwon, W. H. and Pearson, A. E., "A Double Integral Quadratic Cost and Tolerance of Feedback Nonlinearities," *Proc. of Sixteenth Annual Allerton Conf. on Comm., Contr. and Comp.*, U. of Illinois, Urbana, IL, pp. 670-678, October 1978. Full length version accepted for publication in *IEEE Trans. on Auto. Contr.*, vol. AC-24, June 1979.

[2] Wei, K. C. and Pearson, A. E., "On Minimum Energy Control of Commutative Bilinear Systems," *IEEE Trans. on Auto. Contr.*, vol. AC-23, No. 6, pp. 1020-1023, December 1978.

[3] Pearson, A. E., "Nonlinear System Identification With Limited Time Data," *Automatica*, vol. 15, pp. 73-84, January 1979. (A shorter version of this paper appeared in *Proc. of IFAC VII*, vol. 3, pp. 2159-2166, Helsinki, Finland, June 1978).

V. RESEARCH IN PROGRESS

Pearson, A. E. and Mocenigo, J. M., "A Filter for Separating Time Limited Modal Signals." To appear in *Proceedings of 1979 JACC*, Denver, CO, June 1979.

Pearson, A. E. and Chin, Y. K., "Identification of MIMO Systems With Partially Decoupled Parameters." To appear in IEEE Trans. on Auto. Contr., vol. AC-24, August 1979.

VI. M.Sc. THESES

Yu, Kai-Bor, "Modeling, Estimation and Control of a Two-Dimensional Intercept System," M.Sc. Thesis, Brown University, June 1979.

VII. PROFESSIONAL INTERACTIONS

October 5, 1978: Invited paper, "A Double Integral Quadratic Cost and Tolerance of Feedback Nonlinearities," presented at the Sixteenth Annual Allerton Conf., U. of Illinois, Urbana, IL.

May 24, 1979: Participated in the Annual Tristate Conference (Brown U., U. of Conn., U. of Mass., U. of Rhode Island and Yale U), New Haven, CT.

REPORT PREPARED BY: Allan E. Pearson

FOR GRANT: AFOSR-75-2793

Allan E. Pearson
Professor of Engineering
Principal Investigator

Carl Cometta
Executive Officer
Division of Engineering

EAP/jbf
6/6/79