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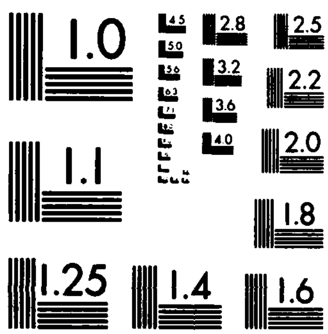

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FINAL TECHNICAL REPORT

STABILIZATION STUDIES

(Grant No. AFOSR 79-0053)

PRINCIPAL INVESTIGATOR

Nhan Levan
Professor
Department of System Science

UNIVERSITY OF CALIFORNIA, LOS ANGELES
SCHOOL OF ENGINEERING AND APPLIED SCIENCE

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CONTENTS

1. INTRODUCTION

This report describes results obtained during the final year of the Grant: February 1, 1983 through January 31, 1984.

2. RESULTS

In [1] stability and state feedback stabilizability of linear distributed parameter systems are studied, using the theory of Hilbert space semigroups of operators. The notion of a "P-contraction" semigroup is introduced. This turns out to be the key tool of this work. A P-contraction semigroup is related to a contraction one via a similarity, or a quasi-affine transformation --depending on whether the operator P is "strictly" positive or positive. This leads to a canonical decomposition for this class of semigroups. Moreover, sufficient conditions for "approximate" stability for the semigroup are obtained by means of this canonical decomposition.

We must note that a main feature of our work is that the operator P can be obtained from the "operator" steady state Riccati equation associated with the infinite time Linear Quadratic Regulator control problem in Hilbert space.

The notion of "approximate" stability has not been considered before. Here we are able to show that as soon as a P-contraction semigroup is uniformly bounded then, if it is "approximately" stable, it is actually stable --i.e., stable over the whole space. Applying these results to the wave equation with a bounded domain, we can show that the system can be strongly stabilized by a state feedback which involves a positve solution of the steady state Riccati equation. Moreover, this stabilization is carried out by means of an energy norm.

In [2] we studies the following problem: "under what conditions will a C_o semigroup $T(t)$, $t \geq 0$, with generator A, be exponentially stable, given that the semigroup $S(t)$, $t \geq 0$, (say) generated by $A - K$ --where K is a bounded linear operator, is exponentially stable?" This problem results from the fact that if a system is strongly stable then it is <u>not</u> possible to exponentially stabilized it by means of a compact feedback. Here we basically find coditions under which it is not possible to exponentially stabilized a distributed parameter system by means of a state feedback. Our results are obtained, first for a general operator K, then for the case in which K is generated from a steady state Riccati equation. An interesting consequence is that, if a semigroup $T(t)$, $t \geq 0$, is not exponentially stable, and it is exponentially stabilized by the feedback $-B^*P$ --where $P \geq 0$ satisfied a steady state Riccati equation -- then there must exist an initial state $x(0)$ for which the control $u(t) = -B^*PT(t)x(0)$, $t \geq 0$, is not square integrable. Moreover, if the semigroup $T(t)$, $t \geq 0$, is contractive and strongly stable, and the operator B is compact, then the steady state Riccati equation does not admit any non-negative solution.

Finally in [3] we concentrates on strong stability of the class of "quasi-affine" transforms of contraction semigroups. Sufficient conditions for these semigroups to be strongly stable on the domain of the generators are found. Our key tool of analysis is the generalization of the LaSalle Invariance Principle to nonfinite dimensional systems. Here we illustrate a case in which the limit set of the Invariance Principle can actually be characterized. The main result of this work is that, in general, approximate controllability implies approximate strong stabilizability --as far as stabilizability via the steady state Riccati equation is concerned.

3. ITEMS SUPPORTED BY THE GRANT (February 1, 1983 - January 31, 1984)

[1] DONG-JO PARK, Stabilizability of Infinite Dimensional Systems and The Steady State Riccati Equation, Ph.D Dissertation, University of California in Los Angeles, School of Engineering and Applied Science, March 1984.

[2] N. LEVAN, Stability of An Exponentially Stabilizable System, IEEE Trans. Automatic Control, (To Appear).

[3] N. LEVAN, Strong Stability of Quasi-Affine Transforms of Contraction Semigroups and The Steady State Riccati Equation, Journal of Optimization Theory & Applications, (To Appear).

4. LIST OF ALL ITEMS SUPPORTED BY THE GRANT (February 1, 1979 - January 31, 1984)

N. LEVAN:

1.-On S-Stability of Hilbert Space Contraction Semigroups, Proc. Inter. Symp. Math. Theory of Networks & Systems, Delft Uni., July 3 - 6, 1979, 405-411.

2.-On the Reduction of a Contraction Semigroup to a Completely Non-Selfadjoint Nonunitary One, Journal Numer. Functional Analysis & Optimization, 1 (6), 1979, 619-631.

3.-Controllability, *-Controllability and Stabilizability, Journal of Differential Equations, 38 (1), 1980, 61-79.

4.-On Some Relationships Between The LaSalle Invariance Principle and The Nagy-Foias Canonical Decomposition, J. Math. Anal. & Appls, 77 (2), 1980, 493-504.

5.-A Note On Uniformly Bounded Hilbert Space Semigroups, J. Math. Anal. & Appls., 77 (2), 1980, 344-350.

6.-Stability and Stabilizability of Nonfinite Dimensional Systems, Proc. 1980 IEEE Inter. Symp. on Circuits & Systems, Vol.1, 290-293.

7.-Passivity, Dissipativity, and Stabilizability, UCLA School of Engr. & Applied Science Technical Report No. UCLA-ENG 82-07, Nov. 1980.

8.-Feedback Stabilization and Perturbation of C_o Semigroups, Proc. 24th Midwest Symp. On Circuits & Systems, 1981, 583-587.

9.-Stabilizability of Hilbert Space Contraction Semigroups: A Scattering Theory Approach, Proc. 3rd IFAC Symp. On Control of Distributed Parameter Systems, Toulouse, France, June 29-July 2, 1982, VI-1 to VI-6.

10. -Canonical Decompositions Of Completely Nonunitary Contractions, J. Math. Anal. & Appls., 1984, (To Appear).

11. -On A Class Of C_o Semigroups In Control Theory, Special Issue in Contemporary Mathematics Series of the AMS entitled "Systems Theory", (To Appear).

12. -Approximate Stabilizability Via The Algebraic Riccati Equation, SIAM J. Contr. & Optimization, (To Appear).

13. -Stability of An Exponentially Stabilizable System, IEEE Trans. Automatic Control, (To Appear).

14. -Strong Stability of Quasi-Affine Transforms of Contraction Semigroups and The Steady State Riccati Equation, J. Optimization Theory & Appls., (To Appear).

T. NAMBU:

1. -Feedback Stabilization For Distributed Parameter Systems of Parabolic Type, III, Rendiconti Del Circolo Matematico Di Palermo, Serie II, 31 (1982), 41-67.

2. -Feedback Stabilization of Diffusion Equations by a Functional Observer, J. of Differential Equations, 43 (2), 1982, 257 - 280.

3. -Feedback Stabilization for Distributed Parameter Systems of Parabolic Type, II, Archive for Rational Mechanics & Analysis, 79 (3), 1982, 241-259.

4. -On The Stabilization of Diffusion Equations: Boundary Observer and Feedback, J. Of Differential Equations, (To Appear).

DONG-JO PARK:

1. -Stabilizability of Infinite Dimensional Systems and the Steady State Riccati Equation, Ph. D Dissertation, UCLA, March 1984.

A.P. ROSS:

1. -The Stability and Stabilizability of Infinite Dimensional Linear Systems Via Lyapunov's Direct Method, Ph.D Dissertation, UCLA, September 1979.

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8