AD-A212 088

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REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S): AFOSR-TR- 89-1201
6a. NAME OF PERFORMING ORGANIZATION: Center for Mathematical System Theory; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: Air Force Office of Scientific Research
6c. ADDRESS (City, State, and ZIP Code): Department of Mathematics, University of Florida, Gainesville, FL 32611	7b. ADDRESS (City, State, and ZIP Code): Directorate of Mathematical & Information Sciences, AFOSR, Bolling AFB DC 20332
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: AFOSR; 8b. OFFICE SYMBOL (If applicable): NM	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: AFOSR-87-0249 ~~and~~ AF~~OSR-87-0~~249A
8c. ADDRESS (City, State, and ZIP Code): Building 410, Bolling AFB DC 20330-6448	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. 61102F; PROJECT NO. 2304; TASK NO. A1; WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Mathematical Techniques for System Realization and Identification (unclassified)

12. PERSONAL AUTHOR(S)
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13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final Report	FROM 880401 TO 890331	1989 June	8

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

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

Research supported by grants AFOSR-87-0429 and AFOSR-87-0249A has emphasized algebraic systems theory and the identification of systems from noisy data. Identification, which is based on mathematical (primarily algebraic) ideas has been the area of our main effort. Much work at the Center has been in preparation of reanalyses of published data and exposition of new methods of analysis of noisy data.

Research on basic aspects of algebraic system theory has also been active. This research contributes to the study of identification, because it is concerned with deep results about system properties in the exact, that is, noise-free case.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL: Lt Col Crowley	22b. TELEPHONE (Include Area Code): (202) 767-5028	22c. OFFICE SYMBOL: NM

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

AFOSR-TR- 89-1201

Mathematical Techniques for
System Realization and Identification

Final Report

June 1989

R. E. Kalman
Principal Investigator

April 1, 1988 through March 31, 1989

U. S. Air Force Office of Scientific Research
Grant Number AFOSR-87-0249
and AFOSR-87-0249 A

Center for Mathematical System Theory
University of Florida

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Dist	Avail and/or Special	
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Research Summary

Research supported in the past few years under this grant at the CENTER FOR MATHEMATICAL SYSTEM THEORY has emphasized two broad areas:

(i) Algebraic system theory.

(ii) Identification of systems from noisy data.

The two topics are related to each other; indeed the new research on identification is based on mathematical (primarily algebraic) ideas and techniques rather than the traditional aproach via probability theory and statistics. During the period reported here, the second topic (studied mainly by the Principal Investigator and visitors) has been the area of main effort.

There is now a large body of new knowledge of identification, both as regards the general strategy of research and many specific results and techniques. In particular, a very careful and in-depth analysis of traditional techniques of statistics such as least squares (regression), principal components, and factor analysis, has shown that these techniques are irreversibly "flawed" because they allow too much role for "prejudices" (usually manifeste[illegible] guesses at the nature of noise), rather than letting the data "speak for itself".

There has been practically no progress in the methodology of identification in the past forty years. As has been argued in KALMAN [1988], it is absolutely necessary to eliminate preconceptions (technically, the prejudices) from the field, not only in order to make progress, but even to assess the limitations and applicability of present methods.

A large amount of work has been done at the Center in the preparation of reanalyses of published real data and the exposition of the new (algebraic, rather than probabilities) methods of analysis of noisy data. A research monograph is in preparation (KALMAN [1989]), as well as at least four additional mathematical papers, some of which have been already presented at high-level research conferences.

Research on basic aspects of algebraic system theory has also been active. (This research contributes indirectly to the study of identification, because it is concerned with deep results about system properties in the exact, that is, noise-free case. Evidently, noise-free identification must be well-understood before one attempts to study the noisy case). In particular, BIRGET [1986-1987] has continued the study of discrete-time, discrete-state systems (automata) from the algebraic point of view; BIRGET's research reported in these papers originated during his postdoctoral tenure (until 1985) at the Center.

EMRE (Postdoctoral fellow in 1986) also continues his work on realization (i.e., noise-free identification) theory with collaborators at the University of Texas at Lubbock. A previous postdoctoral (in the early 1980's) and now a permanent Center member, HAMMER [1987-88] has been very active in research on the algebraic theory of nonlinear systems since rejoining the Center in the summer of 1987.

The research of the Principal Investigator has important implications on the highly controversial debate concerned with the interpretation of quantum mechanics as a physical (i.e., "identifiable") theory. While this is by no means the main thrust of the investigation by the Principal Investigator, he has benefited from a research visit by ACCARDI [1988]. ACCARDI's work (University of Rome, ITALY) on the probabilistics of quantum mechanics began completely independently of the research under the grant but appears to be converging toward it, both in the kind of problems treated and in the mathematical methodology.

PUBLICATIONS SUPPORTED IN PART BY THE GRANT

I. Preprints

L. ACCARDI

[1988] "Cecchini's transition expectations and Markov chains", 6 pages, accepted by the Quantum Probability and Applications IV, Springer Lecture Notes in Mathematcis.

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[1988] "Squeezing corrections to the Bloch equations", 9 pages, submitted to Physical Review.

L. ACCARDI and A. BACH

[1988a] "Central limits of squeezing operators", 15 pages, accepted by the Quantum Probability and Applications IV, Springer Lecture Notes in Mathematics.

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L. ACCARDI, A. FRIGERIO, and Y. G. LU

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L. ACCARDI and J. QUAEGEBEUR

[1988a] "The Ito algebra of quantum Gaussian fields", 36 pages, accepted by the Journal of Functional Analysis.

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[1988] "Quantum random walks and coherent quantum chains", 18 pages, accepted by the Quantum Probability and Applications IV, Springer Lecture Notes in Mathematics.

J. C. BIRGET

[1987] "Two-way automaton computations", 34 pages, accepted by RAIRO, Informatique Theorique.

E. EMRE and J. H. SEO

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E. EMRE, H. TAI, and J. H. SEO

[1987a] "Stabilization of continuous-time linear time-varying systems via transfer matrices and fractional representations, presented in the Proceedings of the American Control Conference, June 1988, 37 pages. [Previous title: Transfer matrices, realization and control of continuous-time linear time-varying systems via polynomial fractional representations]

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J. HAMMER

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[1987] "Assignment of dynamics for nonlinear recursive feedback systems", International Journal of Control, 48 (1988) 1183-1212.

[1988] "On robust stabilization of nonlinear systems", International Journal of Control, 49 (1989) 629-653.

R. E. KALMAN

[1989] IDENTIFICATION (research monograph), Springer, to appear in 1989.

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* Courtesy affiliation only; no direct grant support

(b) Visitors

Short-term visitors for 1985/87

Dr. A. Lindenmayer, University of Utrecht, THE NETHERLANDS

Dr. C. Los, Nomura Research Institute, Inc., New York, NY

Dr. T. Matsuo, Nagoya University, Nagoya, Japan

Dr. J. Rissanen, IBM Almaden Research Center, San Jose, CA

Dr. A. Spanos, Virginia Polytechnic Institute and State University, Blacksburg, VA

Dr. Y. Yamamoto, Kyoto University, JAPAN

Long-term visitors for 1988/89 (one month or more)

Dr. L. Accardi, Universita Roma II, ITALY