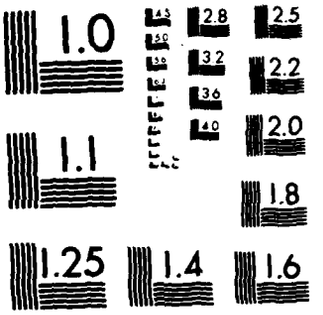
AD-A136 531 FINAL SCIENTIFIC REPORT: 1978 - 1983(U) CALIFORNIA UNIV 1/1
LOS ANGELES DEPT OF SYSTEM SCIENCE A V BALAKRISHNAN
MAR 83 AFOSR-TR-83-1240 AFOSR-78-3550

UNCLASSIFIED F/G 12/1 NL

END
DATE FILMED
1 84
DTIC



FINAL SCIENTIFIC REPORT: 1978 - 1983

Grant No. AFOSR 78-3550

March 1983

Principal Investigator: A. V. Balakrishnan
System Science Department
School of Engineering and
Applied Science
University of California at
Los Angeles

CONTENTS

Chief, Technical Information Division

I. Topics Covered During the Grant-Reporting Period

The research activities during the grant reporting period covered following topics.

1. Non-Linear White Noise Theory
2. Stabilization of Distributed Parameter Systems by Boundary Feedback
3. System Modelling and Identification
4. Control of Flexible Flight Vehicles
5. Random Fields: Filtering and Estimation
6. Control of Randomly Varying Systems
7. Control of Large Space Structures

The progress made on each of them is described below under the corresponding heading. The numbers in parentheses are keyed to the list of publications.

1. Non-Linear White Noise Theory

In a series of papers, including [1], [3] a theory of white noise defined by "finitely additive" or "weak distributions" in a Hilbert space was developed as being closer to the physical noise models than the Wiener process model in the Ito theory. One significant result was a new likelihood-ratio formula which was applied successfully to the problem of identification of aircraft stability and control derivatives from flight-data containing gust response.

2. Stabilization of Distributed Parameter Systems by Boundary Feedback

The problem of controlling systems governed by parabolic or hyperbolic partial differential equations by means of feedback on the boundary was investigated in a number of papers ([7], [8], [14], [15], [22], [23], [24], [25]). Both Dirichlet and Neumann boundary feedback have been treated, following the basic work [38] of the Principal Investigator.

3. System Modelling and Identification

In cooperation with AFFTC Edwards, California, the system identification theory developed by the Principal Investigator was applied to the problem of modelling excess-thrust from flight-test data [2].

The problem of identifying aircraft stability and control derivatives from flight data containing gust response

in which the gust is modelled by the more realistic Von Karman model (nonrational spectrum) as opposed to the simplex (rational spectrum) Dryden model was the subject of a doctoral thesis [13], in which the algorithms were applied to actual flight data.

4. Control of Flexible Flight Vehicles

A technique of generating successively higher order approximations to optimal flap control for a three-degree-of-freedom airfoil in subsonic inviscid flow was presented in [12] based on the earlier general theory [2].

5. Random Fields: Filtering and Estimation

Exact formulas for likelihood ratios for random fields as well as an exact Kalman filtering theory for line-scan of two-dimensional fields were developed in [19] and for circular scan in [20]. In addition a linear smoothing theory and a nonlinear parameter estimation theory using the author's likelihood functional formula based on the white-noise theory are developed in [21]. An application of this theory to geophysics of importance in missile-guidance was presented in [29].

6. Control of Randomly Varying Systems

The problem of feedback control of systems which are subject to random variation of structure modelled as a sudden change from one structure to another at a random time was presented in [28].

7. Control of Large Space Structures

The concept of "strong stability" and "strong stabilizability" was introduced in [30] (as an alternative to exponential stability) of a distributed parameter system with "compact" controller, and feedback controls were developed using (infinite-dimensional) Riccatti equations. This concept was further investigated for colocated sensors and controllers for a beam-like structure, in a Ph.D. dissertation [31].

II. List of Publications

[1] A.V. Balakrishnan: "Non-Linear White Noise Theory," invited paper, Proceedings of the 5th International Conference on Multivariate Analysis, Pittsburgh, 1978, Academic Press.

[2] A.V. Balakrishnan: "Active Control of Airfoils in Unsteady Aerodynamics," Journal of Applied Math and Optimization, Vol. 4, 1978.

[3] A.V. Balakrishnan: "Non-Linear Filtering: White Noise Model," invited paper, Proceedings of the Conference on "Analysis and Optimization of Stochastic Systems," Oxford, September 1978.

[4] A.V. Balakrishnan: "Systems Methodology in Global Modelling: System Identification," Proceedings of the Seminar on Global and Large-Scale System Models, Dubrovik, August 1978, Springer-Verlag.

[5] A.V. Balakrishnan: "Stochastic Bang-Bang Control," invited paper, Proceedings of the IFIP Conference on "Stochastic Differential Systems: Filtering and Control," Vilnius, USSR, September 1978, Springer-Verlag.

[6] C. Benchimol: "Feedback Stabilization in Hilbert Spaces," Journal of Applied Math and Optimization, Vol. 4, 1978.

[7] I. Lasiecka: "Boundary Control of Parabolic Systems: Regularity of Optimal Solutions," Journal of Applied Math and Optimization, Vol. 4, 1978.

[8] I. Lasiecka: "Regularity of Optimal Controls with State and Control Constraints," Journal of Applied Math and Optimization, Vol. 4, 1978.

[9] H. Kunita: "On the Controllability of Non-Linear Systems with Applications to Polynomial Systems," Journal of Applied Math and Optimization, Vol. 5, 1979.

[10] A.V. Balakrishnan: "On Stochastic Bang-Bang Control," Journal of Applied Math and Optimization, Vol. 6, 1980.

[11] A.V. Balakrishnan: "Optimal Control Problems in Aeroelasticity," in Non-Linear Analysis, Akademie-Verlag, Berlin, 1979.

[12] A.V. Balakrishnan: "Stochastic Control Problems in Aeroelasticity," in Proceedings of the 9th IFIP Conference on System Modelling and Optimization, Lecture Notes in Control and Information, Springer-Verlag, 1979.

[13] F. Tung: "Identification of Aircraft Parameters in Turbulence with Non-rational Spectra." Dissertation, 1979.

[14] I. Lasiecka (with R. Triggiani): "A Cosine Operator Approach to Modelling Boundary Input Hyperbolic Equations," Journal of Applied Math and Optimization, Vol. 7, 1981.

[15] I. Lasiecka (with R. Triggiani): "Boundary Feedback Hyperbolic Equations: Regularity and Almost Periodic Stabilization," Journal of Applied Math and Optimization, Vol. 6, 1980.

[16] H. Kotani: "Random Fields," Lectures Notes, Springer-Verlag, 1980.

[17] A. Germani and P. Sen: "White Noise Solutions for a Class of Distributed Feedback Systems with Multiplicative Noise," Automatica, 1979.

[18] A.V. Balakrishnan: "Aircraft Performance Modelling: Theory and Some Preliminary Results," Third Annual Dynamic Performance Workshop, AFFTC, Edwards AFB, 1980.

[19] A.V. Balakrishnan: "Likelihood Ratios and Kalman Filterings for Random Fields," Proceedings of IFIP Conference on "Stochastic Differential Systems," Visegrad, Hungary, 1980.

[20] A.V. Balakrishnan: "On a Class of Riccati Equations in a Hilbert Space," Journal of Applied Math and Optimization, Vol. 7, 1981.

[21] A.V. Balakrishnan: "Some Estimation Problems for Random Fields," invited paper, C. Rao Memorial Volume, Academic Press, 1980.

[22] I. Lasiecka: "On the Analyticity of the Optimal Boundary Control for Parabolic Equations with Quadratic Cost," Journal of Applied Math and Optimization, Vol. 7, 1981.

[23] I. Lasiecka (with R. Triggiani): "Structural Assignment of Boundary Feedback Parabolic Solutions," SIAM Journal on Control, 1980.

[24] I. Lasiecka (with R. Triggiani): "Parabolic Equations with Boundary Feedback via Dirichlet Trace: The Feedback Semigroup," Journal of Functional Analysis, 1980.

[25] I. Lasiecka (with R. Triggiani): "Structural Assignment and Stabilization of Neumann Boundary Feedback Parabolic Equations with Dirichlet Trace in the Feedback Loop," Journal of Applied Math and Optimization, Vol. 6, 1980.

[26] R. Mazumdar: "Recursive Least Squares with a Variable Forgetting Factor," Proceedings of the 2nd Yale Workshop on Applications of Adaptive Systems Theory, May 1981.

[27] A.V. Balakrishnan: "Stochastic Control of Randomly Varying Systems," invited paper, JACC, December 1981, San Diego. Published in the Proceedings.

[28] A.V. Balakrishnan: "A Likelihood Ratio Formula for Random Fields with Application to Physical Geodesy," Journal of Applied Math and Optimization, Vol. 8, 1982.

[29] A.V. Balakrishnan: "Strong Stabilizability and the Steady State Riccati Equation," Journal of Applied Math and Optimization, Vol. 7, 1981.

[30] M. Mackay: "Active Control of Large Flexible Space Structures," Ph.D. dissertation, UCLA, 1983.

BOOK

[31] A.V. Balakrishnan: Applied Functional Analysis, 2nd edition, Springer-Verlag, 1981.

III. Principal Investigator: Biography

1. Invited Speaker: Conference on Multivariate Analysis, Pittsburg, June 1978.
2. Invited Speaker: Seminar on Global and Large-Scale System Models, Dubrovnik, Yugoslavia, August 1978.
3. Invited Speaker: IFIP Conference on "Stochastic Differential Systems: Filtering and Control," Vilnius, USSR, September 1978.
4. Invited Speaker: International Conference on "The Analysis and Optimization of Stochastic Systems," Oxford, England, September 1978.
5. Chairman, Technical Program Committee, 9th IFIP Conference on System Modelling and Optimization, Warsaw, September 1979.
6. Consultant, Dymo Tech Program, Edwards AFB, 1977-78.
7. Awarded NASA "Certificate of Recognition" for Contributions to Aircraft Flight Test -- Extraction of Stability and Control Derivation," June 1978.
8. Team Co-Chairman: Broadly Applicable Technology Section, NASA Workshop on Avionics and Controls, Langley Research Center, June 1978.
9. Invited Speaker: 9th IFIP Conference on System Modelling and Optimization, Warsaw, September 1979.

10. Invited Speaker: Conference on Non-Linear Analysis, East Berlin, September 1979.
11. Chairman: Session on Aircraft Applications, 5th IFAC Symposium on Identification and System Parameter Estimation, Darmstadt, September 1979.
12. Invited Speaker: IFIP Working Conference on Stochastic Differential Systems, Budapest, September 1980.
13. Chairman, International Organizing Committee, IFIP Working Conference on Stochastic Differential Systems, Budapest, September 1980.
14. Member, International Program Committee, 5th IFAC Symposium on Identification and System Parameter Estimation, September 1979.
15. Member, International Scientific Committee, IMACS Conference on "Simulation of Distributed-Parameter and Large-Scale Systems," Patras, Greece, October 1979.
16. 1980 Guillemin Prize for Contributions to Communication and Control Systems; awarded October 1980.
17. Invited Speaker: 10th IFIP Conference on System Modelling and Optimization, New York, September 1981.
18. Chairman, External Review Committee on Control Sciences Programs, University of Minnesota, Minneapolis, May 1980.
19. Managing Editor: Selecta Sovieta Mathematica, published by Birkhäuser, Inc.

20. Chairman, International Program Committee, IFIP Working Conference on "Random Fields and Applications," Mexico, January 1982.
21. Invited Speaker: 3rd International Congress on Probability, Vilnius, USSR, June 1981.
22. Member, Large Scale Systems Steering Committee, IEEE.
23. Chairman, International Program Committee, IFIP Working Conference on Random Fields, Bangalore, India, January 1982.
24. Chairman, Subcommittee on Large Space Structures, COLSS, IEEE.
25. Chairman, International Program Committee, IFIP Working Conference on Mathematical Modelling, Moscow, USSR, July 1982.
26. Seminar Lecturer: University of Florida, April 1981.
27. Seminar Lecturer: University of North Carolina, September 1981.
28. Invited Lecture: "White Noise Theory," International Symposium on the Mathematical Theory of Networks and Systems, Santa Monica, California, August 1981.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

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- 83-1240
6a. NAME OF PERFORMING ORGANIZATION: University of California; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: Air Force Office of Scientific Research
6c. ADDRESS (City, State and ZIP Code): System Science Department, Los Angeles CA 90024	7b. ADDRESS (City, State and ZIP Code): Directorate of Mathematical & Information Sciences, Bolling AFB DC 20332
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: AFOSR; 8b. OFFICE SYMBOL (If applicable): NM	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: AFOSR-78-3550
8c. ADDRESS (City, State and ZIP Code): Bolling AFB DC 20332	10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
61102F	2304	A4	

11. TITLE (Include Security Classification): SEE REMARKS	
12. PERSONAL AUTHOR(S): A.V. Balakrishnan	

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Final	FROM 1/2/82 TO 31/3/83	MAR 83	12

16. SUPPLEMENTARY NOTATION

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

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

During the period of this grant, topics investigated included: nonlinear white noise theory; stabilization of distributed parameter systems by boundary feedback; system modeling and identification; control of flexible flight vehicles; random fields --- filtering and estimation; control of randomly varying systems; and control of large space structures. Thirty technical papers were produced with titles including: "Active control of airfoils in unsteady aerodynamics;" "Identification of aircraft parameters in turbulence with non-rational spectra;" "Aircraft performance modelling --- Theory and some preliminary results;" and "Active control of large flexible space structures."

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS ☐	UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
Dr. Robert N. Buchal	(202) 767- 4939	NM

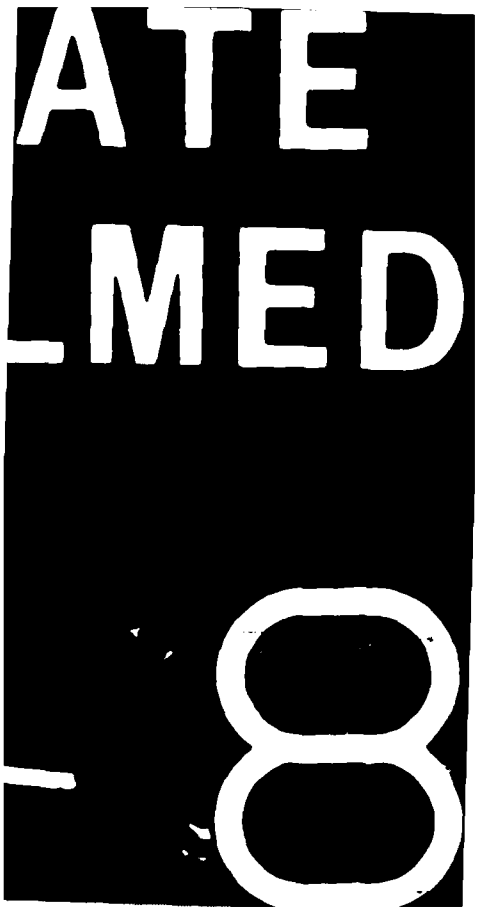
DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

ITEM #11, TITLE: FINAL SCIENTIFIC REPORT: 1978 - 1983, GRANT NO. AFOSR-78-3550


ATE
LMED
8