



# Advances in Control

Edited by

**D. G. Lainiotis and N. S. Tzannes**

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# Advances in Control

*Volume II of a selection of papers from INFO II, the Second International Conference on Information Sciences and Systems, University of Patras, Greece, July 9-14, 1979*

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## P R E F A C E

This volume contains a selection of papers presented at INFO II, the Second International Conference on Information Sciences and Systems, held at the University of Patras, Greece, from July 9th to 14th, 1979. Additional selections of papers from this Conference are published in separate volumes, also by D. Reidel and are entitled "Advances in Communications" and "Applications of Information and Control Systems", respectively.

INFO II, was hosted by the University of Patras and sponsored by, the Ministry of Culture & Sciences, IEEE Automatic Control Society, IEEE Information Theory Group, IEEE Systems -Man and Cybernetics Society, World Organization of General Systems and Cybernetics, IEEE Greece, and the Greek Society for Cybernetics and Systems. It was the second such Conference held at the University of Patras, the first one having taken place from August 19th to 24th, 1976, with its papers published by the Hemisphere Publishing Corporation in a three volume set, entitled "Applications and Research in Information Sciences and Systems".

INFO II, then, was the second high level Conference on these important topics in the Eastern Mediterranean Region. The reason that these conferences have been established is because we feel strongly that the topics covered have reached a high degree of maturity in this region, both from the point of view of theory and application. The applications areas are especially important to the Mediterranean region in view of the Common Market connections of such countries as France, Italy and Greece and the anticipated admission of Spain. In view of this, a major objective of the conferences is to focus attention on these important technical subjects and to facilitate the exchange of information and cross-fertilization of ideas between researchers of the Mediterranean region and those of the rest of the world, thereby promoting research and development by the region's engineers, researchers and academicians.

The Conference keynoted by Prof. J.L.Lions, France, Prof. L.A. Zadeh, U.S.A., and Prof. M.Dertouzos, U.S.A., was highly successful as evidenced by the attendance of over 250 scientists and engineers from approximately 30 countries, and by the presentation of over 200 technical papers by well-known scientists and engineers from around the world.

The technical program of the Conference consisted of technical sessions that covered all-important aspects of control, information processing/communications, and computers. In particular, the-



re were numerous technical sessions covering all-important aspects of control, such as, control theory, control applications, estimation, identification, adaptive systems, linear systems, stability, cybernetics, computational methods, and simulation. The program also included many sessions on information processing/communications such as, information theory, coding, signal analysis, signal processing, communication theory, satellite communications, pattern recognition and image processing. Moreover, there were several sessions on computers, in particular on computer systems, computer communication networks, and automata. Finally, the technical program included numerous sessions on important applications of systems technology, such as, power, energy modeling and planning, earth resources, transportation, economics and management, and physiological systems.

In view of the broad scope of the Conference technical program and the extensive coverage of many important aspects of systems theory and applications by internationally known researchers, we hope that this collection of papers will be a useful supplement to the published literature and textbooks used for research and teaching.

For the success of the Conference we are indebted to a great many people and institutions, primarily to the authors of the papers, without whom the conference would not have existed, and this book would not have materialized. We are particularly indebted to the great majority of them who paid some or all of their own expenses.

We are greatly indebted to the University of Patras for hosting the Conference, and for its financial support, as well as to the various other institutions and companies, whose financial support was essential for the success of the Conference. We would also like to thank the above mentioned scientific societies for adding their name as conference co-sponsors.

Finally, in a personal vein, we would like to thank the session chairmen, and the members of various conference committees, for their enthusiasm and dedication with which they worked in making INFO II a reality.





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SECTION I

A SHORT REPORT ON THE OPTIMAL CONTROL OF DISTRIBUTED SYSTEMS

The keynote paper

by

J.-L. Lions

College de France  
and I.N.R.I.A.

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## A SHORT REPORT ON THE OPTIMAL CONTROL OF DISTRIBUTED SYSTEMS

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## ABSTRACT

A short review of some of the most important problems arising in the optimal control of systems governed by Partial Differential Equations (Distributed Systems).  
Connections with free boundary problems are emphasized.

## INTRODUCTION

*Distributed systems* are systems which are governed by Partial Differential Equations ; more precisely they are modelled through a set of equations which are Partial Differential Equations.

These systems depend on *control variables* (or control functions), denoted here by  $v$  ; for any given  $v$  , the *state of the system*  $y(v)$  is given by the solution of a boundary value problem involving the Partial Differential Equations referred to above and appropriate *boundary conditions* (and, in case of evolution problems, *initial conditions*).

To every couple  $\{v, y(v)\}$  we associate a real number  $J(v)$  which is the *cost function*.

The problem is to minimize  $J(v)$ ,  $v$  being subject to a number of constraints (which can be "implicit", that is which can be defined through constraints on  $y(v)$ ).

The final aim is to obtain *constructive algorithms*, which can be implemented *in real time* (in case of evolution problems).

It is quite clear that in such a general setting, these questions involve "all" the theory of Partial Differential Equations, "all" the theory of the numerical approximation of Partial Differential Equations (finite differences, finite elements), "all" the theory of calculus of variations and the theory of nonlinear programming, etc.. It is beyond the scope of this report <sup>(1)</sup>.

In what follows we want first to put the above considerations in a more precise form ; this is the aim of Section 1.

We want then to give (in Section 2) a simple example where one can obtain Necessary and Sufficient conditions for optimality.

In Section 3 we present situations (which often arise in practical applications) where the control variable is of an unusual structure.

It often happens that the cost function we want to minimize is *not* differentiable ; this is in particular the case for the *optimal control of free surfaces* - which is also a situation which is important from the point of view of applications. Some indications on this question are given in Section 4.

*Perturbation theory* is going to play a more and more important role in these questions ; we briefly indicate some examples in Section 5.

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(1) And of the Author of the report ...