Jan Lunze

Feedback Control of Large-Scale Systems

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with 74 figures and 26 examples

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Author:

Prof. Dr.-Ing. Jan Lunze
Ruhr-Universität Bochum
Lehrstuhl für Automatisierungstechnik und Prozessinformatik
44780 Bochum
Lunze@atp.rub.de

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Preface

Present-day technologies rely on the cooperation of many different machines, reactors, robots or transportation systems. All their parts are linked by common resources, by material flows or through information networks. If such systems are to be controlled, their analysis and control problems become very complex. That is, these tasks cannot be solved simply by using faster computers with larger memories. They necessitate new ideas for decomposing and dividing the analysis and control problems of the overall system into rather independent subproblems and for dealing with the uncertainties of the model and the lack of information about the system to be controlled.

For a typical large-scale system, there is no complete model available for the overall system, but each model describes only a part of the whole system. The system has to be controlled not by a single unit but by several separate feedback loops, each of which deals with only a subset of the measured signals and operates on a subset of the actuators. All together, these feedback loops represent a decentralized controller. Moreover, the analysis and design tasks have to be solved by different decision makers which can only communicate in a restricted way. Owing to this requirement, decentralized structures of decision making have to be used in the analysis of interconnected systems and the design of decentralized controllers.

The theory of large-scale systems is devoted to the problems that arise from the large size of the system to be controlled, the uncertainties of the models, and the information structure constraints. It is based on several new ideas which utilize the internal structure of interconnected systems, yield to decentralized controllers and reduce the requirements on the scope and accuracy of the model of the plant. The theory answers the fundamental question of how to break down a given control problem into manageable subproblems which are only weakly related to each other and can, therefore, be solved by separate but cooperating decision units. The resulting control strategies and feedback laws can be applied using multicomputer configurations whose separate computing units work independently without coordination or with weak coordination and information exchange.

This book presents the basic methods showing how multivariable feedback theory has to be extended to solve analytical and design tasks for interconnected systems. Emphasis is placed on the derivation of methods which have a decentralized information structure, that is which involve several weakly coupled decision units for analysing the given system or designing the controller. Preference is given to the clear presentation of simple and effective techniques which provide the basis for a large number of specific and sophisticated methods that have been derived only recently. Many of these refinements are outlined or at least mentioned in the bibliographical notes at the ends of the chapters.

The book is aimed at students, researchers and practising engineers. The theoretical background of interconnected feedback systems is presented together with a detailed engineering interpretation of the relevant methods and results. The different approaches, which have led to the large number of available analytical and design methods and many recent results, are presented together with their interrelationships, advantages and drawbacks.

Two different kinds of examples are used. Simple numerical examples give an intuitive understanding of the methodology, illustrate the significance of the results or algorithms, provide counterexamples to conjectures or make trends obvious. Practical application studies demonstrate how control problems for large-scale systems can be solved by means of the various methods. They show that some of the concepts presented here have already been applied to industrial systems such as multiarea power systems, glass furnaces, lines of moving vehicles, or to the water quality control of rivers. Some of the examples are used several times to illustrate different phenomena encountered in interconnected systems.

The presentation follows lectures which I have given regularly since 1976 to undergraduate and graduate students at the Universities of Technology in Dresden and Ilmenau. Readers should be acquainted with the theory of linear multivariable control systems. The basic results of matrix algebra and graph theory are given in the appendices.

Many co-researchers have influenced my thinking on the topic of this book. I am indebted to Professor K. Reinisch who introduced me as a student at the Technische Hochschule Ilmenau to the theory of large-scale systems as early as 1973. It was fascinating to be involved with the development of this theory since those early days. Most of the material of this book has been collected during my research at the Zentralinstitut für Kybernetik und Informationsprozesse in Dresden. My first supervisor, Dr J. Uhlig, channelled my interests towards decentralized control for application to the national electric power system. I have benefited greatly from stimulating discussions, correspondence or

common research work with Professors U. Korn and U. Jumar (Magdeburg), D. D. Šiljak (Santa Clara), K. Reinschke (Cottbus), L. Bakule (Prague), V. Vesely (Bratislava) and many others.

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Dresden, March 1990 J. Lunze