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BJÖRN WITTENMARK

Report 7329 (C) November 1973
Lund Institute of Technology
Division of Automatic Control

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Division of Automatic Control,
Lund Institute of Technology,
Lund, Sweden.

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1. RESEARCH PROJECTS

Given below are some short descriptions of the research projects at the Division.

1.1 Linear System Theory

A theoretical framework has been developed for linear multivariable systems based upon geometric state space concepts. The combined servo and regulator probelm is solved, using properties of minimal systems inverses. In this context special analysis has been performed on systems which are nonminimum phase in a multivariable sense. The notation of poles and zeroes has been extended to multivariable systems. Explicit criteria can be given on suitable choices of measured variables and control variables in a given system. The output or incomplete state feedback problem has been attacked by an approximation method. A state feedback is approximated by an output feedback using successive weightings on a dominant eigen-space.

The filtering and prediction problems for linear time-varying systems have been attacked using operator factorization. The estimation problem for linear gaussian systems with unknown initial state has also been treated.

1.2 System Identification

The project has mainly been concentrated on the development of algorithms and program packages, comparisons of different methods, studies of theoretical problems in connection with identification and parameter estimation, and applications to a great variety of industrial, biological, and economical systems.

An extensive program library of identification is now available. In particular, we have an interactive identification program package for the process computer PDP-15. The use of interactive programs increases the efficiency considerably.

Identification of single-input single-output systems can now be performed straightforwardly. Multivariable and nonlinear identification is under current research.

1.3 Adaptive Control

The research on adaptive control systems has been concentrated on a special class of regulators called self-tuning regulators. These are derived to tune regulators for processes with constant but unknown parameters. The self-tuning regulators have been implemented on several industrial processes. The experiences are good concerning the performance of the regulator.

The research is now concentrated on convergence properties and development of self-tuning regulators for multivariable systems.

1.5 Computational Methods

The research projects in computational control can roughly be separated into four different groups.

- Optimal control of nonlinear systems
- Optimizing methods for constrained finite-dimensional problems
- The program library
- Applications

The research on optimal control will be concentrated on developing efficient methods for the numerical solution of different optimal control problems.

The research on optimization methods for finite-dimensional problems has a two-fold goal. Firstly, to implement different algorithms previously developed at the Division and secondly, to act as a source of ideas for optimal control problems.

A powerful program library has proven to be of extremely great value for all the different research projects. It will thus be continuously developed and updated.

1.6 Computer-Aided Design of Control Systems

Modern control theory often gives rise to numerical calculations that even for small problems can be prohibitive if they must be done by hand. Therefore, computers have become an important tool for the control engineers. However, human intuition and judgement can never be replaced by computers, so the advantages of the two must be merged somehow. This is achieved through the use of interactive computer programs. At the Division two interactive programs have been developed. One, SYNPAC, is intended for simulation of linear dynamic systems with a feedback designed by using linear quadratic theory. The other, IDPAC, is intended for data analysis and identification. Both contain commands for manipulation of input-output data, as well as plotting.

These programs that have been used, both for research and education, are also available for outside uses to an extent determined by available computer time.

1.7 Power Systems

A computer program which generates time independent linear state space models of a multiple machine power system has been written. This is a necessary base for further development of control algorithms for this system.

Linear quadratic control theory has been applied to the problem of increasing the damping of a multi machine power system. To avoid complete information exchange between all power stations, a new technique of approximation control laws is applied to a power system with three generators.

Other investigated problems are the economic load dispatch problem and state estimation in power systems.

1.8 Ship Dynamics and Ship Control

There are two current projects in this field. The first one intends to apply process identification techniques to the determination of ship dynamics. The identification is performed on data obtained from full-scale experiments where the rudder is perturbated and the course, yaw rate, and the sway velocity are measured. The second project is to design an adaptive autopilot for course keeping and manoeuvering. The autopilot will be implemented as a computer program, and it will be tested on 350 000 tdw tankers.

1.9 Biological Control

Identification of impulse responses from tracer data have been performed. Although the data does not contain enough information for a correct system, description wanted parameters can be obtained with good accuracy. Similar considerations lie behind the work on renal clearance measurements together with the Department of Clinical Physiology, Lund, University Hospital. The feasibility of a new method using a few blood samples and external radioactive measurements is under investigation. The indicator infusion is controlled in order to get steady state conditions as soon as possible.

Works in this area have also been done on a genetic population model and on the dosage on digitalis.

1.10 Control Systems in Climatized Buildings

Experiments concerning the control of the air temperature of a full-scale test room have been performed. The room is heated by electrical radiators. Several types of control laws to keep constant room air temperature under varying conditions have been tested. The control laws were implemented on a process computer, which was connected to the control equipment at

the test room via telefon wire. The experiments clearly show that control laws based on dynamic models of the system have better performance than the conventional ones. A model for the hotwater supply of a block of buildings has been used for forecasting. The model contains a periodic deterministic part and a term proportional to the outdoor temperature.

2. EDUCATION IN AUTOMATIC CONTROL

2.1 Undergraduate courses

The Division has courses for students from the physical, electrical, mechanical, and chemical engineering departments. We have the following courses:

Introductory course 200 students

(Linear continuous time systems. Time and frequency domain analysis).

Lectures	28 hours
Exercises	14 hours
Laboratory work	14 hours

Advanced course 50 students

(Non-linear systems, sampled data systems, and stochastic systems).

Lectures	42 hours
Exercises	28 hours
Laboratory work	14 hours

Small course for chemical engineers 50 students

(Frequency domain analysis).

Lectures	21 hours
Exercises	14 hours

Systems techniques 50 students

(For mechanical engineers).

Lectures	42 hours
Exercises	21 hours
Project	14 hours

Computers in control systems 75 students

(Hardware and software for process computers in control systems).

Lectures	28 hours
Exercises	14 hours
Laboratory work	14 hours

2.2 Graduate courses

During each year 3 - 6 courses are given. During the academic year 72/73 the following courses were lectured:

- Linear Quadratic Control Theory
- Control Theory and Economic Policy
- Filtering Problems in Linear Infinite Dimensional Systems
- Modelling of Dynamic Industrial Processes
- Linear System Theory

3. LIST OF PERSONNEL

Professor	Karl Johan Åström
Lecturer	Gustaf Olsson Björn Wittenmark
Research assistant	Krister Mårtensson
Research engineer	Leif Andersson Gunnar Bengtsson Ulf Borisson Ivar Gustavsson Lars Jensen Claes Källström Sture Lindahl Lennart Ljung Staffan Selander Torsten Söderström Johan Wieslander
Teaching assistant	Hilding Elmqvist Jan Holst Bo Leden Jan Stemnby
Programmer	Tommy Essebo
Laboratory engineer	Rolf Braun
Graduate students (Ph.D.)	Torkel Glad Lars Pernebo
Office personnel	Britt-Marie Carlsson Marianne Moore Eva Schildt

4. PUBLICATIONS

Lists of technical reports, published papers, and master theses can be found in the annual reports of the Division. See for instance

(1) Åström, K. J.: Process Control 1971 - 1972, Report 7221, Division of Automatic Control, September 1972.

(2) Åström, K. J. and Olsson, G.: Process Control 1972 - 1973, Report 7329, Division of Automatic Control, September 1973.

(3) Wittenmark, B.: Master Theses in Automatic Control 71/72, Report 7230, Division of Automatic Control, December 1972.

(4) Wittenmark, B.: Master Theses in Automatic Control 72/73, Report 7340, Division of Automatic Control, November 1973.

Given below is the number of different publications from the Division during the academic year 72/73

o Technical reports	44
o Published papers	8
o Contributions to conferences	11
o Master theses	18
o Internal technical reports	30