

Stochastic optimal control and its connection with estimation

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Abstract: The paper describes a formulation of the stochastic control problem in which the primary and secondary performance indices are distinguished. A minimisation and averaging principle, defining the connection between the two indices, is established, and some conclusions resulting from the principle are described. The generalised certainty equivalence principle, in some new notation, is also presented. Finally, the original generalised recursive estimation problem, which is equivalent to the stochastic optimal control problem, is formulated and solved.

1 Introduction

Many papers have been written about the stochastic optimal control problems where the available information is incomplete and the mean value of a performance index is minimised. A stochastic version of dynamic programming is sometimes used to solve such problems [1-17]. This requires certain assumptions about changing the order of minimisation and averaging operations which, in many papers, are not sufficiently exactly expressed.

The present paper contains some of the author's results, most of which are published in Polish [6-11]. In Sections 2 and 3 the problem is formulated and primary and secondary performance indices are distinguished. In Section 4 the solution of the problem is described and the so-called minimisation and averaging (Min-E) principle formulated. Section 5 contains conclusions resulting from the Min-E principle. In Section 6 the original description of the generalised certainty equivalence principle is presented. In Section 7 the generalised recursive estimation problem is formulated and solved; it is also shown that the last problem is equivalent to the stochastic optimal control problem.

2 Description of primary problem

Let us consider a system described by the difference equation

$$x_{n+1} = f_n(x_n, u_n, w_n) \quad (1)$$

where x_n , u_n , w_n are the vectors of state, control and disturbance, respectively, f_n are definite functions of their arguments, n denotes discrete time, i.e. $n = 0, 1, \dots, N$, and N is an integer defining the stopping time.

The primary performance index, which we would like to minimise, has the form

$$I = \sum_{n=0}^N L_n(x_n, u_n, v_n) \quad (2)$$

where x_n are vector random variables and L_n are scalar definite functions.

We assume that the control variables u_n do not influence the random variables w_k , v_k for $k > n$, $k, n = 0, 1, \dots, N$. We also assume that the appropriate probability distribution functions for random variables w_n , v_n and the initial state x_0 are given.

Because the primary problem contains a large number

of random variables the primary performance index (eqn. 2) also takes a random value. Thus, in the case of incomplete information it is impossible to find the solution of the primary problem, i.e. to define the controls u_n for which the primary performance index takes its minimal value. The formulation of a secondary problem, which will be soluble, depends upon the available information.

3 Secondary problem formulation

We assume that the information about the system consists of two parts. The first part results from past experience and takes the form of appropriate probability distribution functions; the second part results from current measurements to be made in the system and takes the form of a vector of current information \hat{y}_n . This vector \hat{y}_n contains information available at the time n and obtained from measurements. We assume that the vector \hat{y}_n accumulates results of measurements from the past, i.e. all components which occur in the vector \hat{y}_{n-1} also occur in the vector \hat{y}_n , together with the results of current measurements \hat{y}_n . The above assumption is made only to concentrate the mind; there is no necessity to make this assumption, e.g. in the case when the current measurements \hat{y}_n obtained in each step contain the variables x_n , v_n and form Markov processes. Generally speaking, the components of the vectors \hat{y}_n should be chosen so that it will be possible to define the appropriate probability distribution functions which are used at the time of performing the conditional averaging operations to be defined later.

Let \hat{Y}_n and U_n be the sets of vectors \hat{y}_n and u_n , respectively, i.e. $\hat{y}_n \in \hat{Y}_n$ and $u_n \in U_n$, $n = 0, 1, \dots, N$. The sequence of the functions $u_n = h_n(\hat{y}_n)$, $n = 0, 1, \dots, N$, each of which maps \hat{Y}_n into U_n and for which the secondary performance index of the form

$$\bar{R}(h) = E \sum_{n=0}^N L_n(x_n, h_n(\hat{y}_n), v_n) \quad (3)$$

takes a definite value, will be called the admissible control strategy. Here E denotes the operation of averaging and the notation $\bar{R}(h)$ has been introduced to stress that the value of the secondary performance index depends upon the set of functions $h = [h_0^T, h_1^T, \dots, h_N^T]^T$.

Secondary problem

Among admissible control strategies of the considered system the optimal strategy $u_n = h_n^*(\hat{y}_n)$, $n = 0, 1, \dots, N$, is to be found for which the secondary performance index takes its minimal value, i.e.

$$\bar{R}(h^*) = \text{Min}_h \bar{R}(h) \quad (4)$$

Stochastic Optimal Linear Estimation And Control

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Stochastic Optimal Linear Estimation and Control James S. Meditch, 1969 *Modern Control System Theory* M. Gopal, 1993 About the book The book provides an integrated treatment of continuous time and discrete time systems for two courses at postgraduate level or one course at undergraduate and one course at postgraduate level It covers mainly two areas of modern control theory namely system theory and multivariable and optimal control The coverage of the former is quite exhaustive while that of latter is adequate with significant provision of the necessary topics that enables a research student to comprehend various technical papers The stress is on interdisciplinary nature of the subject Practical control problems from various engineering disciplines have been drawn to illustrate the potential concepts Most of the theoretical results have been presented in a manner suitable for digital computer programming along with the necessary algorithms for numerical computations *Estimation and Control over Communication Networks* Alexey S. Matveev, Andrey V. Savkin, 2009-04-05 This book presents a systematic theory of estimation and control over communication networks It develops a theory that utilizes communications control information and dynamical systems theory motivated and applied to advanced networking scenarios The book establishes theoretically rich and practically important connections among modern control theory Shannon information theory and entropy theory of dynamical systems originated in the work of Kolmogorov This self contained monograph covers the latest achievements in the area It contains many real world applications and the presentation is accessible **Advanced Kalman Filtering, Least-Squares and Modeling** Bruce P. Gibbs, 2011-03-29 This book is intended primarily as a handbook for engineers who must design practical systems Its primary goal is to discuss model development in sufficient detail so that the reader may design an estimator that meets all application requirements and is robust to modeling assumptions Since it is sometimes difficult to a priori determine the best model structure use of exploratory data analysis to define model structure is discussed Methods for deciding on the best model are also presented A second goal is to present little known extensions of least squares estimation or Kalman filtering that provide guidance on model structure and parameters or make the estimator more robust to changes in real world behavior A third goal is discussion of implementation issues that make the estimator more accurate or efficient or that make it flexible so that model alternatives can be easily compared The fourth goal is to provide the designer analyst with guidance in evaluating estimator performance and in determining correcting problems The final goal is to provide a subroutine library that simplifies implementation and flexible general purpose high level drivers that allow both easy analysis of alternative models and access to extensions of the basic filtering Supplemental materials and up to date errata are downloadable at <http://booksupport.wiley.com> *Optimal Control and Estimation* Robert F. Stengel, 2012-10-16 Graduate level text provides introduction to optimal control theory for stochastic systems emphasizing application of basic concepts to real problems Invaluable as a reference for those already familiar with the subject Automatica [Catalog of Copyright Entries. Third Series](#) Library of Congress.

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The Ocean Engineering Handbook Ferial El-Hawary,2000-12-28 Compiled by an internationally acclaimed panel of experts this is the most complete reference of its kind It provides comprehensive coverage of important areas of the theory and practice of oceanic coastal engineering and technology The well organized text includes five major sections Marine Hydrodynamics and Vehicles Control Modeling Considerations Position Control Systems for Offshore Vessels Applications of Computational Intelligence in the Ocean's Environment and Fiber Optics in Oceanographic Applications Designed as a traditional handbook it offers a detailed look ocean engineering including thorough coverage of position control theory and implementation **Defence from Floods and Floodplain Management** John Gardiner,Odon Starosolszky,V. Yevjevich,2012-12-06

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David Hilbert Over the last 15 years I have given lectures on a variety of problems in nonlinear functional analysis and its applications In doing this I have recommended to my students a number of excellent monographs devoted to specialized topics but there was no complete survey type exposition of nonlinear functional analysis making available a quick survey to the wide range of readers including mathematicians natural scientists and engineers who have only an elementary knowledge of linear functional analysis I have tried to close this gap with my five part lecture notes the first three parts of which have been published in the Teubner Texte series by Teubner Verlag Leipzig 1976 1977 and 1978 The present English edition was translated from a completely rewritten manuscript which is significantly longer than the original version in the Teubner Texte series The material is organized in the following way Part I Fixed Point Theorems Part II Monotone Operators Part III Variational Methods and Optimization Parts IV jV Applications to Mathematical Physics The exposition is guided by the following considerations a What are the supporting basic ideas and what intrinsic interrelations exist between them 3 In what relation do the basic ideas stand to the known propositions of classical analysis and linear functional analysis y What typical applications are there VII Preface viii Special emphasis is placed on motivation

Decision Making with Imperfect Decision Makers Tatiana Valentine Guy,Miroslav Kárný,David H. Wolpert,2011-11-13 Prescriptive Bayesian decision making has reached a high level of maturity and is well supported algorithmically However experimental data shows that real decision makers choose such Bayes optimal decisions surprisingly infrequently often making decisions that are badly sub optimal So prevalent is such imperfect decision making that it should be accepted as an inherent feature of real decision makers living within interacting societies To date such societies have been investigated from an economic and gametheoretic perspective and even to a degree from a physics perspective However little research has been done from the perspective of computer science and associated disciplines like machine learning information theory and neuroscience This book is a major contribution to such research Some of the particular topics addressed include How should we formalise rational decision making of a single imperfect decision maker Does the answer change for a system of imperfect decision makers Can we extend existing prescriptive theories for perfect decision makers to make them useful for imperfect ones How can we exploit the relation of these problems to the control under varying and uncertain resources constraints as well as to the problem of the computational decision making What can we learn from natural engineered and social systems to help us address these issues

Dealing with Complexity Mirek Karny,Kevin Warwick,Vera Kurkova,2012-12-06 In almost all areas of science and engineering the use of computers and microcomputers has in recent years transformed entire subject areas What was not even considered possible a decade or two ago is now not only possible but is also part of everyday practice As a result a new approach usually needs to be taken in order to get the best out of a situation What is required is now a computer s eye view of the world However all is not rosy in this new world Humans tend to think in two or three dimensions at most whereas computers can without complaint work in n dimensions where n in practice gets bigger and bigger each year As a

result of this more complex problem solutions are being attempted whether or not the problems themselves are inherently complex. If information is available it might as well be used but what can be done with it. Straightforward traditional computational solutions to this new problem of complexity can and usually do produce very unsatisfactory, unreliable and even unworkable results. Recently, however, artificial neural networks, which have been found to be very versatile and powerful when dealing with difficulties such as nonlinearities, multivariate systems and high data content, have shown their strengths in general in dealing with complex problems. This volume brings together a collection of top researchers from around the world in the field of artificial neural networks. Virtual Environments and Scientific Visualization '96 Martin Göbel, Jaques David, Pavel Slavik, Jarke van Wijk, 2012-12-06. Selected papers from this year's Workshops on Virtual Environments and on Visualization in Scientific Computing are included in this volume. The papers on VE discuss Virtual Environment System architecture, communication requirements, synthetic actors, crowd simulations and modeling aspects, application experience in surgery support, geographic information systems and engineering and virtual housing systems. Contributions from the Visualization workshop are presented in four groups: volume rendering, user interfaces in scientific visualization, architecture of scientific visualization systems and flow visualization. *COSMIC Software Catalog*, 1987.

Handbook of Digital Signal Processing Douglas F. Elliott, 2013-10-22. FROM THE PREFACE: Many new useful ideas are presented in this handbook including new finite impulse response (FIR) filter design techniques, half-band and multiplierless FIR filters, interpolated FIR (IFIR) structures and error spectrum shaping. Concurrent Design of Products, Manufacturing Processes and Systems Ben Wang, 1999-01-27. Methods presented involve the use of simulation and modeling tools and virtual workstations in conjunction with a design environment. This allows a diverse group of researchers, manufacturers and suppliers to work within a comprehensive network of shared knowledge. The design environment consists of engineering workstations and servers and a suite of simulation, quantitative computational, analytical, qualitative and experimental tools. Such a design environment will allow the effective and efficient integration of complete product design, manufacturing process design and customer satisfaction predictions. This volume enables the reader to create an integrated concurrent engineering design and analysis infrastructure through the use of virtual workstations and servers, provide remote, instant sharing of engineering data and resources for the development of a product system, mechanism, part, business and/or process and develop applications fully compatible with international CAD/CAM/CAE standards for product representation and modeling.

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Table of Contents Stochastic Optimal Linear Estimation And Control

1. Understanding the eBook Stochastic Optimal Linear Estimation And Control
 - The Rise of Digital Reading Stochastic Optimal Linear Estimation And Control
 - Advantages of eBooks Over Traditional Books
2. Identifying Stochastic Optimal Linear Estimation And Control
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Stochastic Optimal Linear Estimation And Control
 - User-Friendly Interface

4. Exploring eBook Recommendations from Stochastic Optimal Linear Estimation And Control
 - Personalized Recommendations
 - Stochastic Optimal Linear Estimation And Control User Reviews and Ratings
 - Stochastic Optimal Linear Estimation And Control and Bestseller Lists
5. Accessing Stochastic Optimal Linear Estimation And Control Free and Paid eBooks
 - Stochastic Optimal Linear Estimation And Control Public Domain eBooks
 - Stochastic Optimal Linear Estimation And Control eBook Subscription Services
 - Stochastic Optimal Linear Estimation And Control Budget-Friendly Options
6. Navigating Stochastic Optimal Linear Estimation And Control eBook Formats
 - ePub, PDF, MOBI, and More
 - Stochastic Optimal Linear Estimation And Control Compatibility with Devices
 - Stochastic Optimal Linear Estimation And Control Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Stochastic Optimal Linear Estimation And Control
 - Highlighting and Note-Taking Stochastic Optimal Linear Estimation And Control
 - Interactive Elements Stochastic Optimal Linear Estimation And Control
8. Staying Engaged with Stochastic Optimal Linear Estimation And Control
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Stochastic Optimal Linear Estimation And Control
9. Balancing eBooks and Physical Books Stochastic Optimal Linear Estimation And Control
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Stochastic Optimal Linear Estimation And Control
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Stochastic Optimal Linear Estimation And Control
 - Setting Reading Goals Stochastic Optimal Linear Estimation And Control
 - Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Stochastic Optimal Linear Estimation And Control
 - Fact-Checking eBook Content of Stochastic Optimal Linear Estimation And Control
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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