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

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

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. $n = 0, 1, \ldots, N$, and N is an integer defining the stopping time.

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

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

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

We assume that the control variables u_k do not influence the random variables w_n, r_n for $k > n$, $k, n = 0, 1, \ldots, N$. We also assume that the appropriate probability distribution functions for random variables w_n, r_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 $\bar{y}_n$. This vector $\bar{y}_n$ contains information available at the time n and obtained from measurements. We assume that the vector $\bar{y}_n$ accumulates results of measurements from the past, i.e. all components which occur in the vector $\bar{y}_{n-1}$ also occur in the vector $\bar{y}_n$ together with the results of current measurements 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 $\bar{y}_n$ obtained in each step contain the variables x_n, r_n and form Markov processes. Generally speaking, the components of the vectors $\bar{y}_n$ 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 $\bar{Y}_n$ and U_n be the sets of vectors $\bar{y}_n$ and u_n, respectively, i.e. $\bar{y}_n \in \bar{Y}_n$ and $u_n \in U_n$, $n = 0, 1, \ldots, N$. The sequence of the functions $u_n = h_n(\bar{y}_n)$, $n = 0, 1, \ldots, N$, each of which maps $\bar{Y}_n$ into U_n and for which the secondary performance index of the form

$$\bar{I}(h) = E \sum_{n=0}^{N} L_n[x_n, h_n(\bar{y}_n), r_n] \tag{3}$$

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

Secondary problem

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

$$\bar{I}(h^o) = \min_{h} \bar{I}(h) \tag{4}$$

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Stochastic Optimal Linear Estimation And Control

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Stochastic Optimal Linear Estimation And Control:

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 *Optimal Control and Estimation* Robert F. Stengel,1994-09-20 An excellent introduction to optimal control and estimation theory and its relationship with LQG design invaluable as a reference for those already familiar with the subject Automatica This highly regarded graduate level text provides a comprehensive introduction to optimal control theory for stochastic systems emphasizing application of its basic concepts to real problems The first two chapters introduce optimal control and review the mathematics of control and estimation Chapter 3 addresses optimal control of systems that may be nonlinear and time varying but whose inputs and parameters are known without error Chapter 4 of the book presents methods for estimating the dynamic states of a system that is driven by uncertain forces and is observed with random measurement error Chapter 5 discusses the general problem of stochastic optimal control and the concluding chapter covers linear time invariant systems Robert F Stengel is Professor of Mechanical and Aerospace Engineering at Princeton University where he directs the Topical Program on Robotics and Intelligent Systems and the Laboratory for Control and Automation He was a principal designer of the Project Apollo Lunar Module control system An excellent teaching book with many examples and worked problems which would be ideal for self study or for use in the classroom The book also has a practical orientation and would be of considerable use to people applying these techniques in practice Short Book Reviews Publication of the International Statistical Institute An excellent book which guides the reader through most of the important concepts and techniques A useful book for students and their teachers and for those practicing engineers who require a comprehensive reference to the subject Library Reviews The Royal Aeronautical Society

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