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David Levanony · Peter E. Caines

Stochastic Lagrangian Adaptation

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ISSN 2191-8198 ISSN 2191-8201 (electronic)
SpringerBriefs in Mathematics
ISBN 978-3-031-73757-2 ISBN 978-3-031-73758-9 (eBook)
https://doi.org/10.1007/978-3-031-73758-9

Mathematics Subject Classification: 60G17, 93E35, 62F12, 62F30 , 93D21, 93E20, 93E24

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

Chapter 1
Introduction

Abstract An overview of stochastic adaptive control from its birth to date is provided. In particular, the concept of Certainty Equivalence (CE) adaptive control is highlighted together with the fact that in some of its principal forms it requires consistent parameter estimation. Since sample-path Persistent Excitation (PE) of the associated regression vector process ensures consistency, various attempts to secure that property are discussed. The PE requirement may be abandoned when certain control-biased estimation methods are utilized. One such methodology is realized in this work which is built upon a geometric study of limit sets of parameter estimates which give rise to closed-loop indistinguishable dynamics.

Keywords Stochastic adaptive control (SAC) · Certainty equivalence (CE) · Recursive least squares (RLS) · Vanishing dither injection · Stochastic differential equation (SDE) · Strong consistency · Persistent excitation (PE) · Constrained optimization · Linear quadratic (LQ) adaptive control · Set of indistinguishable closed-loop dynamics · Biased parameter estimates

One of the earliest formulations of stochastic adaptive control (SAC) was the self-tuning regulator (STR) introduced by Åström and Wittenmark [1]. The STR is a Certainty Equivalence adaptive control scheme for systems described by discrete-time autoregressive moving average (ARMAX) models relating system control inputs, measured outputs and exogenous disturbance processes. Certainty Equivalence adaptive controllers consist of: (i) a learning mechanism which recursively generates parameter estimates, and (ii) a standard control law with the values of the unknown system parameters replaced by their estimates at any instant in time. The STR of Åström and Wittenmark [1] and Clarke and Gawthrop [12] generates recursive least squares (RLS) parameter estimates which are used in an output feedback minimum variance control law. Properties of the behavior of the STR scheme were obtained in that work subject to the assumption of the consistency (i.e., convergence to true values) of the parameter estimates.

Subsequently, in the work of Goodwin, Ramadge and Caines [19] (see Goodwin and Sin [18], and Caines [4, Chapter 12]) the first complete asymptotically optimal

D. Levanony, P. E. Caines, *Stochastic Lagrangian Adaptation*, SpringerBriefs in Mathematics, https://doi.org/10.1007/978-3-031-73758-9_1