[Review of the book Identification and Stochastic Adaptive Control, H.F. Chen & L. Guo, 1991]

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HAN-FU CHEN and LEI GUO, *Identification and stochastic adaptive control*. Basel, etc.: Birkhäuser, 1991. 435 p., prijs Sf 128,- - (hc) (Systems & control: foundations & applications). ISBN 3-7643-3597- 1.

A nice example of adaptive control occurs in the electronic thermostats that are found in an increasing number of homes. A thermostat of this type not only allows it proud owner to specify a temperature pattern that should be followed over the day; the instrument is also intelligent enough to monitor the time it takes to heat up the house in the morning. If it finds that the desired temperature is not reached at the specified time, it will start earlier the next day. Such an electronic thermostat has an *adaptation* mechanism built into it, which at least in this respect puts it on a par with many other recently developed pieces of technology and, for that matter, with living organisms.
Adaptive control is the branch of control theory that is specifically concerned with the design of control laws that employ adaptation to unknown system parameters. The book under review provides an extensive treatment of adaptive control for linear stochastic systems. This subject has been covered before in several textbooks (standard references include the books by Goodwin and Sin (*Adaptive Filtering, Prediction and Control*, 1984) and Kumar and Varayia (*Stochastic Systems: Estimation, Identification, Adaptive Control*, 1986)), but Chen and Guo provide many more details in particular concerning convergence and stability analysis. The authors have contributed very substantially to the field and the book is to a large extent based on their own work.
It is not very easy to come up with systematic methods of constructing adaptive controllers. A head–on optimization approach leads to the dual– control problem: control actions not only serve to reach a specified goal, but also to learn more about the system, and the problem is to weigh these two purposes against each other. This problem seems to be intractable for most classes of systems and performance criteria, the most notable exception being the so–called multi–armed bandit problem. The large body of knowledge that is available for the control of systems with known parameters suggests another way of attack. In the "indirect" approach, estimates of the system parameters are updated at every step, and the control actions are the ones that would be taken by a controller designed for a system with the estimated parameters. Actually the control actions have to be modified slightly in order to make sure that the system is sufficiently probed for the estimates to converge to the true parameter values. Exactly how to do this is one of the main subjects in the book by Chen and Guo. The estimation process itself is called "identification" and has been important enough for the authors to include in the title of their book.
The book starts with two chapters reviewing stochastic calculus and martingale convergence theorems, including some refined results that are needed in the context of adaptive control. Then the authors discuss the optimal control of stochastic linear systems with known parameters and recursive parameter estimation schemes for systems with exogenous inputs. They next show almost sure optimality of indirect adaptive control laws when the sum of squares of a tracking error is to be minimized; for the stochastic gradient algorithm this is the celebrated result of Goodwin, Ramadge, and Caines, for the (less simple) extended least squares algorithm the result is their own. The authors continue with a discussion of parameter convergence, and give very precise estimates using control laws that include just the right amount of "dither" to ensure parameter

convergence without impairing the long– term quality of performance.

Up to this point, parameter estimation is done under the assumption that the number of parameters is known (fixed system order). This assumption is removed in Chapter 7, where the authors propose a new information criterion for order estimation which they call CIC, following the well–known criteria AIC and BIC. (In these acronyms. "IC" stands for "information criterion", "A" stands for "Akaike", "B" stands for the second letter of the alphabet, and "C" stands for "control".) They return to the analysis of adaptive control schemes in the next chapter, working under various assumptions on the degree to which the controlled system is unknown. After a chapter on approximation of systems of infinite order, the point comes where the authors also drop the assumption that the unknown parameters are constant in time. It may reasonably be argued that time–varying systems are the real challenge of adaptive control theory, but their analysis is difficult due to the fact that the stability theory for systems with time–dependent parameters is far from complete. Chen and Guo, however, provide a number of useful results on the stability of estimates provided by the Kalman filter and by the popular least mean squares algorithm. These results are next applied to prove the stabilizing property of certain indirect adaptive control schemes. The book concludes with a brief chapter on continuous–time systems.

Despite the introductory chapters, the book of Chen and Guo is probably too specialized to serve as a textbook. It will be very useful, however, to researchers in adaptive stochastic control and in adaptive signal processing. Also those who are interested in the identification of systems with nonstationarities due to exogenous inputs and/or time–varying parameters will be able to profit from the detailed and careful analysis in the book.

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