Automatica, Vol. 20, No. 5, pp. 499–500, 1984
Pergamon Press Ltd. Printed in Great Britain
International Federation of Automatic Control

EDITORIAL NOTE

One of the most challenging, interesting and active fields of Automatic Control is that of adaptive control. Intuitively, it is appealing because of its kinship with human capabilities and its connotations of artificial intelligence all closely associated with the magic of computer control. However, converting intuitive concepts into practice is often difficult; unexpected problems usually arise as has been the case of applying adaptive control. Although it has been used successfully in numerous applications, unexplained phenomena have been encountered both theoretically and practically while attempting to obtain general, methodical procedures for designing adaptive control systems. Consequently numerous problems remain to be solved before the full potential of adaptive control can be realized. At the present time, the field is changing rapidly and there are many points of confusion. Therefore we are fortunate in having Professors Brian Anderson and Lennart Ljung to organize this Special Issue on Adaptive Control and to provide a perspective about the field including the problems, progress and status at the present time.

G. S. AXELBY
Editor-in-Chief

Adaptive Control, Where Are We?

THE RAPID DEVELOPMENT of adaptive control in the seventies and eighties has brought the field to a position with a fairly established collection of basic techniques and theoretical tools, as well as with some widely recognized gaps. Many successful industrial and semi-industrial applications together with emerging general purpose adaptive regulators as commercial products embody the first step from theory to practice. The Editors have aimed at reflecting this status of the field in the present Special Issue of *Automatica* on Adaptive Control. A number of articles give a perspective of the state-of-the-art in different subfields, while others report new research results.

If one aggregates the knowledge contained in the text of this issue together with the knowledge contained in all past papers on the subject of adaptive control, one can still perceive many wide gaps. The gap to which people are most prone to refer is that between theory and applications. Certainly there is such a gap. However, the Editors would prefer to characterize this gap in another way, by saying that there is a lack of qualitative, or semi-quantitative, conceptual aids, especially those invoking frequency domain ideas, for designing adaptive control systems. Design engineers are not happy when presented just with adaptive control algorithms. They need a conceptual framework in which to think about those algorithms, which at the same time is a framework which coheres with their existing knowledge concerning non-adaptive problems. Such a framework is still largely lacking.

To go along with such a framework there is also needed a general overall stability theory that adequately reflects robustness issues. Such a theory would have to encompass the treatment of adaptive control problems of a type hitherto hardly started in the theoretical literature—for example, problems in which a system description is given in state variable form with most entries of the state variable matrices known, and with few entries depending on possibly fewer unknown parameters. A general overall stability theory would also clarify precisely what assumptions are generally necessary on the noise in certain algorithms. Should one really have to look for a positive real condition? Are boundedness assumptions really crucial?

Another dimension of the theory–practice gap is the task of satisfactorily achieving technological transfer. Should there be adaptive control in the undergraduate curriculum? What form of continuing education courses is best? How should one go about educating customers? Then there is the even more subtle question: what should a piece of industrial hardware look like, which both does a job and promotes confidence in users who have little or no conceptual understanding of adaptive control?

The above remarks have embedded within them a mention of several challenging theoretical problems. Let us list one or two more, the solutions of any of which can be expected to flow on to the applications area with practical advantage. First, when working with black box models, it is common to describe transfer functions in terms of numerator and denominator coefficients, which can exhibit great sensitivity problems. What then are better forms of parameterization of transfer functions than those hitherto used, which would still offer tractability of the underlying adaptive problem? In an entirely different direction, we draw the theorist's attention to the comparative lack of attention paid to the problem of tracking time-varying parameters. Analyses are fairly incomplete, and the suggested algorithms all look fairly primitive. As a final challenge to the adaptive control theorist we would pose the problem of providing a unifying view of adaptive control. It would not be unfair to say that adaptive control has from some points of view in the past looked like a mass of competing ideologies, and today looks like a collection of parallel ideologies. Is it possible to seek a synthesis?

Lastly, we think it is important to recall that the completion of a number of problems of adaptive control may well depend on prior completion of some yet open problems of non-adaptive control. It seems to us that there is at this moment not a full understanding of robustness issues for multivariable systems, nor of procedures for designing low order controllers for a high order system, nor the problem of doing efficient recursive identification (with no feedback) in the face of varying dynamics.

Let us finally say that a large number of papers were submitted to this Special Issue. Problems of revisions and deadlines have meant that a number of papers are still being considered for possible publication, in regular issues of *Automatica*. The story of adaptive control is certainly to be continued.

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