Adaptive Control (2nd Edition)

By Karl Johan Astrom, Bjorn Wittenmark

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Editorial Review

From the Inside Flap

Adaptive control is a fascinating field for study and research. It is also of increasing practical importance, since adaptive techniques are being used more and more in industrial control systems. However, there are still many unsolved theoretical and practical issues. Goal of the Book

Our goal is to give an introduction and an overview of the theoretical and practical aspects of adaptive control.

Since knowledge about adaptive techniques is widely scattered in the literature, it is difficult for a newcomer to get a good grasp of the field. In the book we introduce the basic ideas of adaptive control and compare different approaches. Practical aspects such as implementation and applications are presented in depth. These are very important for the understanding of the advantages and shortcomings of adaptive control. This book has evolved from many years of research and teaching in the field.

After learning the material in the book a reader should have a good perspective of adaptive techniques, an active knowledge of the key approaches, and a good sense of when adaptive techniques can be used and when other methods are more appropriate. The New Edition

Adaptive control is a dynamic field of research and industrial applications. Much new knowledge has appeared which by itself motivates a new edition.

We have used the first edition of the book to teach a wide variety of audiences, in regular university courses, courses to engineers in industry, and short courses at conferences. These experiences combined with advances in research, have shaped the major revisions made in the new edition. We have also benefited from feedback of students and colleagues in industry and universities, who have used the first edition of the book.

New chapters have been added, and the material has been reorganized. Most of the chapters have been substantially revised. In the revision we have also given more emphasis to the connection between different design methods in adaptive control. There is a major change in the way we deal with the theory. In the first edition we relied on mathematics from a wide variety of sources. In the new edition we have to a large extent developed the results from first principles. To make this possible we have made stronger assumptions in a few cases, but the material is now much easier to teach. The reorganization of the material also makes it easier to use the book for different audiences.

The first edition had two introductory chapters; they have now been compressed to one. In the first edition we started with model-reference adaptive systems following the historical tradition. In the second edition we start with parameter estimation and the self-tuning regulator. This has several advantages, one is that students can start to simulate and experiment with computer-based adaptive control at a much earlier state, another is

the system identification gives the natural background and the key concepts required to understand many aspects of adaptive control.

The material on self-tuning control has been expanded substantially by introducing an extra chapter. This has made it possible to give a strict separation between deterministic and stochastic self-tuners. This is advantageous in courses which are restricted to the deterministic case.

The chapter on model-reference adaptive control has been expanded substantially. The key results on stability theory are now derived from first principles. This makes it much easier to teach to students who lack a background in stability theory. A new section on adaptive control on nonlinear systems has also been added.

The reorganization makes the transformation from algorithms to theory much smoother. The chapter on theory now naturally follows the development on nonlinear stability theory. The presentation of the theory has been modified substantially. A new section on stability of time-varying systems has been added. This makes it possible to get a much better understanding of adaptation of feedforward gains. It also is a good transition to the nonlinear case. Material on the nonlinear behavior of adaptive systems has also been added. This adds substantially to the understanding of the behavior of adaptive systems.

The chapter on practical aspects and implementation has been rewritten completely to reflect the increased experience of practical use of adaptive control. It has been very rewarding to observe the drastically increased industrial use of adaptive control. This has influenced the revision of the chapter on applications. For example, adaptive control is now used extensively in automobiles.

Many examples and simulations are given throughout the book to illustrate ideas and theory. Numerous problems are also given. There are theoretical problems as well as problems in which computers must be used for analysis and simulations. The examples and problems give the reader good insight into properties, design procedures, and implementation of adaptive controllers. To maintain a reasonable size of the book we have also done careful pruning.

To summarize, new research and new experiences have made it possible to present the field of adaptive control in what we hope is a better way. Outline of the Book

Background Material

The first chapter gives a broad presentation of adaptive control and background for its use. Real-time estimation, which is an essential part of adaptive control, is introduced in Chapter 2. Both discrete-time and continuous-time estimation are covered.

Self-tuning Regulators and Model-reference Adaptive Systems

Chapters 3, 4, and 5 give two basic developments of adaptive control: self-tuning regulators (STR) and model-reference adaptive systems (MRAS). Today we do not make a distinction between these two approaches, since they are actually equivalent. We have tried to follow the historical development by mainly treating MRAS in continuous time and STR in discrete time. By doing so it is possible to cover many aspects

of adaptive regulators. These chapters mainly cover the ideas and basic properties of the controllers. They also serve as a source of algorithms for adaptive control.

Theory

Chapter 6 gives deeper coverage of the theory of adaptive control. Questions such as stability, convergence, and robustness are discussed. Stochastic adaptive control is treated in Chapter 7. Depending on the background of the students, some of the material in Chapters 6 and 7 can be omitted in an introductory course.

Broadening the View

Automatic tuning of regulators, which is rapidly gaining industrial acceptance, is presented in Chapter 8. Gain scheduling is discussed in Chapter 9. Even though adaptive controllers are very useful tools, they are not the only ways to deal with systems that have varying parameters. Since we believe that it is useful for an engineer to have several ways of solving a problem, alternatives to adaptive control are also included. Robust high-gain control and self-oscillating controllers are presented in Chapter 10.

Practical Aspects and Applications

Chapter 11 give suggestions for the implementation of adaptive controllers. The guidelines are based on practical experience in using adaptive controllers on real processes. Chapter 12 is a summary of applications and description of some commercial adaptive controllers. The applications show that adaptive control can be used in many different types of processes, but also that all applications have special features that must be considered to obtain a good control system.

Perspectives

Finally, Chapter 13 contains a brief review of some areas closely related to adaptive control that we have not been able to cover in the book. Connections to adaptive signal processing, expert systems, and neural networks are given. Prerequisites

The book is for a course at the graduate level for engineering majors. It is assumed that the reader already has good knowledge in automatic control and a basic knowledge in sampled data systems. At our university the course can be taken after an introductory course in feedback control and a course in digital control. The intent is also that the book should be useful for an industrial audience. Course Configuration

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Computer simulation is an indispensible tool for understanding the behavior of adaptive systems. Most of the simulations in the book are done by using the interactive simulation package Simnon, which has been developed at our department. Simnon is available for IBM-PC compatible computers and also for several workstations and mainframe computers. Further information can be obtained from SSPA Systems, Box 24001, S-400 22 Göteborg, Sweden, e-mail: simnon@sspa.se. The macros used in the simulations are available for anonymous FTP from ftp.control.lth.se/pub/books/adaptive_control/. Adaptive systems can of course also be simulated using other tools. Supplements

Complete solutions are available from your sales representative. Course lec-tures, lab exercises, homework projects, final project, and copies of transparencies are available on the World Wide Web at control.lth.se/~kursar. Wanted: Feedback

As teachers and researchers in automatic control, we know the importance of feedback. We therefore encourage all readers to write to us about errors, misunderstandings, suggestions for improvements, and also about what may be valuable in the material we have presented. Acknowledgments

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