

## AUTOMOTIVE CONTROL SYSTEMS

This engineering textbook is designed to introduce advanced control systems for vehicles, including advanced automotive concepts and the next generation of vehicles for Intelligent Transportation Systems (ITS). For each automotive-control problem considered, the authors emphasize the physics and underlying principles behind the control-system concept and design. This is an exciting and rapidly developing field for which many articles and reports exist but no modern unifying text. An extensive list of references is provided at the end of each chapter for all topics covered. This is currently the only textbook, including problems and examples, that covers and integrates the topics of automotive powertrain control, vehicle control, and ITS. The emphasis is on fundamental concepts and methods for automotive control systems rather than the rapidly changing specific technologies. Many of the text examples, as well as the end-of-chapter problems, require the use of MATLAB and/or Simulink.

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## Preface

This textbook is organized in four major parts as follows:

- I. *Introduction and Background* is an introduction to the topic of automotive control systems and a review of background material on engine modeling, vehicle dynamics, and human factors.
- II. *Powertrain Control Systems* includes topics such as air–fuel ratio control, idle-speed control, spark-timing control, control of transmissions, control of hybrid-electric vehicles, and fuel-cell vehicle control.
- III. *Vehicle Control Systems* covers cruise control and headway-control systems, traction-control systems (including antilock brakes), active suspensions, vehicle-stability control, and four-wheel steering.
- IV. *Intelligent Transportation Systems (ITS)* includes an overview of ITS technologies, collision detection and avoidance systems, automated highways, platooning, and automated steering.

With multiple chapters in each part, this textbook contains sufficient material for a one-semester course on automotive control systems. The coverage of the material is at the first-year graduate or advanced undergraduate level in engineering. It is assumed that students have a basic undergraduate-level background in dynamics, automatic control, and automotive engineering.

This textbook is written for engineering students who are interested in participating in the development of advanced control systems for vehicles, including advanced automotive concepts and the next generation of vehicles for ITS. This is an exciting and rapidly developing field for which numerous articles and reports exist. An extensive list of references, therefore, is provided at the end of each chapter for all topics covered. Due to the breadth of topics treated, the reference lists are by no means comprehensive, and new studies are always appearing. However, the lists cover many major contributions and the basic concepts in each sub-area. This textbook is intended to provide a framework for unifying the vast literature represented by the references listed at the end of each chapter. It is currently the only textbook, including problems and examples, that covers and integrates the topics of automotive powertrain control, vehicle control, and ITS.

The emphasis is on fundamental concepts and methods for automotive control systems rather than the rapidly changing specific technologies. For each

automotive-control problem considered, we emphasize the physics and underlying principles behind the control-system concept and design. Any one of the many topics covered (e.g., engine control, vehicle-stability control, or platooning) could be discussed in more detail. However, rather than treating a specific control problem in its full complexity, we use each automotive control application as an opportunity to focus on a key engineering aspect of the control-design problem. For example, we discuss the importance of regulating the air–fuel ratio in engine control, the benefits for vehicle dynamics of reducing the vehicle side-slip angle in four-wheel steering and vehicle-stability control, the importance of predictive/preview action in the material on driver modeling, the concept of string stability for platoons and autonomous cruise-control systems, and the role of risk homeostasis in active-safety-systems design.

We also use various automotive-control applications to focus on specific control methodologies. For example, the Smith predictor for control of time-delay systems is introduced in air–fuel ratio control; linear quadratic optimal estimation and control is introduced for active suspensions; adaptive control using recursive least squares estimation is introduced in the chapter on cruise-control systems; and sliding-mode control is introduced in the discussion of traction-control systems. However, all of these methods can be applied to many other automotive-control problems.

End-of-chapter problems are included and many are used in our courses as homework and/or examination problems. Throughout the text, we include examples to illustrate key points. Many of these examples, as well as the end-of-chapter problems, require the use of MATLAB and/or Simulink. It is assumed that students are familiar with these computational engineering tools; for those who are not, we highly recommend the *Control Tutorials for MATLAB and Simulink* Web site ([www.engin.umich.edu/class/ctms](http://www.engin.umich.edu/class/ctms)) for self-study.

This textbook is based on course notes originally developed by A. Galip Ulsoy during the mid-1990s, then refined and added to by both Ulsoy and Huei Peng during a period of fifteen years of teaching this material to beginning graduate students at the University of Michigan, Ann Arbor. The students are primarily from mechanical engineering disciplines, but students with a suitable background from other engineering disciplines also are included, as well as practicing engineers in the automotive industry who take the course through distance-learning programs and short courses.

We sincerely thank all of our former students for their useful feedback, which led to many improvements in and additions to this material. We also welcome your comments so that we can continue to improve future versions. The current textbook was rewritten extensively from those course notes in collaboration with Melih Çakmakçı, who was not only a former student who took the course but also has worked in the automotive industry as a control engineer for a decade. He brings an additional perspective to the material from his extensive industrial experience.

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