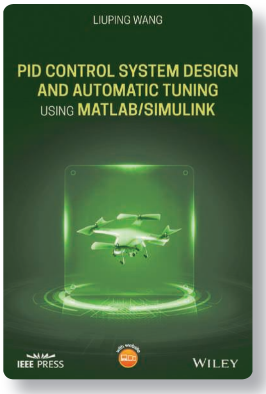
IEEE Control Systems welcomes suggestions for books to be reviewed in this column. Please contact either Scott R. Ploen, Hong Yue, or Thomas Schön, associate editors for book reviews.



Wiley-IEEE Press, 2020, ISBN: 978-1-119—46934-6, 368 pages, US$135.00.

PID CONTROL SYSTEM DESIGN AND AUTOMATIC TUNING USING MATLAB/SIMULINK

by LIUPING WANG

Reviewed by Antonio Visioli

Proportional-integral-derivative (PID) controllers are undoubtedly the most employed controllers in industry, and they have significantly contributed to the impact of control systems in society [1]. In spite of having been used for 100 years and extensively researched [2], it is recognized that, in certain industrial settings, their design is still not done properly, thereby leading to a loss in both production quality and quantity. In fact, methodologies that have been devised for the reduction of the commissioning time (such as automatic tuning techniques) and improvement of overall performance (such as optimized tuning rules) are often not applied because operators and practitioners lack the knowledge to implement these techniques. In this context, this book is a very welcome addition to the PID control literature as it aims to reduce the gap between theory and practice and foster technology transfer from academia to industry.

Indeed, the topics included in the book are useful for students and practitioners in different fields to better understand how to design a PID controller and address the many issues that are faced in practice. The only prerequisites that are assumed of the reader are a basic knowledge of feedback control systems and dynamic systems (for example, transfer functions, frequency response, and state-space models).

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CONTENTS

Chapter 1 presents an introduction to PID control. Specifically, the roles of the proportional, integral, and derivative actions are first outlined. An introduction to tuning rules is then given. From the many rules proposed in the literature [3], only a few of them are reviewed. However, a clear idea of how tuning rules can be used (generally by first estimating a simple model of the process and then applying given formulas that determine the PID gains from the process parameters) and how they are selected (the selection of a particular rule involves many factors and is not a trivial matter) are emphasized.

Chapter 2 addresses closed-loop stability with the analysis of different sensitivity transfer functions. The Routh–Hurwitz and Nyquist criteria are described, and the concepts of gain and phase margin are reviewed. The sensitivity and complementary sensitivity functions are then utilized to demonstrate that control requirements (such as setpoint following and disturbance rejection) are usually conflicting. The use of a two-degree-of-freedom control structure can be very helpful in this context. The modeling of uncertainty and the issues related to robust stability are also considered. All concepts are described with specific reference to PID controllers so that the reader can understand the main issues that arise in the design process.

Chapter 3 covers model-based PID and resonant controller design and starts with the analytical design of PI(D) controllers for processes with simple first- or second-order models. Different PID configurations are considered in this context. Next, the pole-assignment approach is analyzed for resonant controllers. Unlike PID controllers, they have a pair of imaginary poles that makes them particularly suitable for those applications (for example, power electronics and mechanical systems) where reference and disturbance signals are of a sinusoidal type. Finally, feedforward control schemes for disturbance rejection are introduced.

Chapter 4 covers the implementation of PID controllers and addresses the discretization of the PID control law, either in position or velocity form, by discussing practical issues such as the choice of the sampling rate and the effects of quantization errors. In this context, antiwindup methodologies are explained.

Chapter 5 discusses disturbance observer-based PID and resonant controllers. A unified approach to integral and resonant modes is introduced through disturbance estimation, yielding a significant simplification in the management of actuator limitations and the implementation of antiwindup functionality. How to address the presence of additional periodic components in the reference or disturbance signal for resonant controllers is also considered.

Chapter 6 focuses on the PID control of nonlinear systems and explains how the model of a system can be linearized and the PID controller can be tuned based on the linearized model. The use of a gain-scheduling approach to handle different operating conditions is also presented.

Chapter 7 introduces the general design procedure for a cascade control system. The advantages of using cascade control when there are disturbances and nonlinearities in actuators (that is, the presence of dead zones, quantization errors, and backlash) are illustrated.

Chapter 8 covers PID controller design for complex systems. The design of PID controllers for high-order systems using frequency response information (for example, gain and phase margin specifications) is explained. A method that allows the specifications of two points of the loop transfer function is also presented. Finally, tuning rules for integral processes are proposed.

Chapter 9 on the automatic tuning of PID controllers presents different relay-feedback methodologies for the estimation of process characteristics that are used to tune the controller. In this context, both self-regulating and non-self-regulating (integral) processes are considered.

Finally, Chapter 10 discusses case studies related to the design of a cascade-structure PID control system for multirotor unmanned aerial vehicles. Specifically, the attitude control of both a quadrotor and a hexacopter are considered. Beginning with modeling the dynamics of the system, the selection of the control structure is motivated, and the relay-feedback automatic-tuning procedure outlined in Chapter 9 is then applied to determine the parameters of a PID controller. This chapter nicely shows how practical issues are handled via a real application.

SUMMARY

The main feature of this book is the presence of many detailed worked examples that help the reader understand the underlying concepts. The reader is guided in developing Matlab scripts (also available from the book's associated website) that help to clearly outline the sequence of steps associated with each design technique. There are also study questions, provided after each section, designed to evaluate whether the reader fully understands the chapter topics. Numerical and simulation problems are also presented at the end of each chapter.

Overall, the pedagogical approach followed in this text is appreciated and commendable. This book is suitable for those students and practitioners who have been exposed to a single control course [4] and want to learn more about PID controllers or are asked to work with them in an industrial setting. It is worth emphasizing that, due to the inclusion of resonant controllers and a chapter dedicated to unmanned aerial vehicles, this book addresses general areas of application and is not only limited to process control problems. In summary, this book is a very good reference for those who want to deepen their knowledge about PID control without requiring a strong background in control theory. Further advancements in the field can then be learned from other more advanced books [5]–[7] once the basic concepts have been mastered.

REVIEWER INFORMATION

Antonio Visioli (antonio.visioli@unibs.it) received the Laurea degree in electronic engineering from the University of Parma, Italy, in 1995 and the Ph.D. degree in applied mechanics from the University of Brescia, Italy, in 1999. He is currently a full professor of control systems at the University of Brescia, Brescia, I-25123, Italy. His research interests include industrial controllers, mechatronics, dynamic-inversion-based control, fractional control, and anesthesia control. He has authored or coauthored three research monographs; one edited book; one international textbook; and more than 300 publications in international journals, book chapters, and conference proceedings. He is the chair of the IFAC Technical Committee on Education, a member of the Technical Committee on Education of the IEEE Control Systems Society, and a member of the subcommittee on Industrial Automated Systems and Control of the IEEE Industrial Electronics Society Technical Committee on Factory Automation. He is a Senior Member of IEEE.

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