CONCLUSIONS

This book, written by some of the main contributors to the subject, covers an important new perspective on PID control. The book is of interest to practicing engineers, graduate students, and researchers working in the systems and control area. The materials are understandable to average readers with a basic knowledge of systems and control. The book is very well written and can be used for self-study and as a reference.

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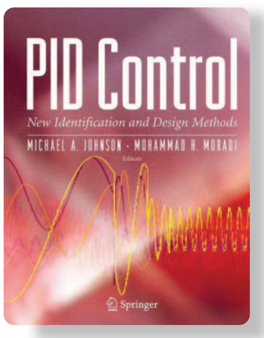

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PID Control: New Identification and Design Methods

BY MICHAEL A. JOHNSON AND MOHAMMAD H. MORADI

Despite significant strides in the development of advanced control schemes over the past two decades, the classical proportional-integral-derivative (PID) controller and its variants remain the controllers of choice in many industrial applications. While the computational capability of modern-day control implementation environments continues to increase, PID controllers remain an engineer's preferred choice because of their structural simplicity, reliability, and the favorable ratio between performance and cost. Beyond these benefits, PID control offers simplified dynamic modeling, lower user-skill requirements, and minimal development effort, which are issues of substantial importance to engineering practice [3].

PID Control: New Identification and Design Methods explores the continuing fascination with PID control. As noted by the editors in the preface, the book was conceived as a set of chapters on new ideas being investigated, with a more appropriate title being "*some* new identification and design methods." The goal is not to provide comprehensive coverage of all new developments in the field but rather to highlight some promising novel directions.

The text is an edited volume containing 13 contributed chapters from 18 authors. The authors' intended use of the book is as a textbook for advanced courses, a reference and self-study guide for academic researchers and practitioners, a source for new ideas, and a channel for enabling contact among PID control researchers. Each chapter is consistently structured with a description of learning objectives, presentation of background material, theoretical development, demonstrations through case studies involving simulated or experimental examples, and individual references for each chapter.

CONTENTS OF THE BOOK

Following a presentation of background material, the book is devoted to describing methods that involve increasing amounts of model information and sophistication. The main categories are:

- *model-free methods*, which do not rely on explicit identification of significant model information
- *nonparametric model methods*, which involve identifying model points of a nonparametric model, such as a frequency response
- *data-intensive methods*, which lie in between nonparametric and parametric approaches; these methods include subspace methods, which depend on significant process data, as well as fuzzy logic methods
- *parametric model methods*, where the starting point is a known transfer function model.

Chapters 1 and 2 provide background material on PID control that is meant to serve as a foundation for the ensuing chapters. Chapter 1, authored by M.A. Johnson, introduces the basic technology of PID control. Implementation aspects of PID control, such as bumpless forms that minimize derivative kick, are described. The chapter also includes descriptions of selected commercial implementations of PID control. Since very little of this information is presented in standard texts, I deem this presentation as particularly useful. Chapter 2, coauthored by M.A. Johnson and M.H. Moradi, focuses on PID control fundamentals. The content of this chapter is more in line with what one would find in a typical academic textbook, with topics spanning from dynamic modeling to multivariable PID forms. Overall, Chapters 1 and 2 present solid reference material on PID control basics and fundamentals, constituting one of the strongest sections of the book.

Chapter 3, coauthored by J. Crowe and M.A. Johnson, discusses online model-free methods, with emphasis on the iterative feedback tuning (IFT) method attributed to [2]. Such methods rely on the process to directly generate gradient information needed for optimization, without requiring any explicit model computations. A controller parameter-cycling tuning method attributed to the first author, which performs the gradient and Hessian generation more efficiently than IFT, is presented and evaluated in the second half of the chapter.

Chapters 4 and 5 focus on nonparametric methods for PID tuning through the concept of relay feedback, a well-known technique that experimentally locates critical points in the frequency response that can then be used for controller tuning. Chapter 4, written by K.K. Tan, T.H. Lee, and R. Ferdous, describes the fundamentals of relay feedback. The material in this chapter is similar to what can be found in a text such as [1]. Besides controller tuning, the use of relay methods for controller performance assessment is illustrated. The chapter also includes a presentation of an experimental example. Chapter 5, by M.H. Moradi and M.R. Katebi, discusses the use of relay feedback for multivariable systems. Various schemes for relay-feedback experiments that can be applied to multivariable systems are described by the authors, with a presentation of corresponding algorithms for controller design. The methods in Chapter 5 are applied to academic examples involving the 2×2 Wood-Berry distillation column model and a 3×3 hypothetical linear system. In contrast to Chapter 4, neither experimental results nor more demanding examples are presented on this topic.

Chapters 6 and 7, both coauthored by J. Crowe and M.A. Johnson, focus on phase-locked loop methods. Phase-locked loops are feedback loops that lock on to a frequency associated with a phase or gain specification. These techniques have an advantage over relay feedback methods in that they can be applied under conditions of significant load disturbances and noise, circumstances in which the standard relay approach fails to provide satisfactory results. However, the time required for these techniques to reach the desired frequency point is usually longer. A thorough comparison to relay approaches is provided in these chapters. Chapter 6 describes the basic underlying theory, while Chapter 7 focuses on the algorithms and associated technology involved with implementing the methods for PID autotuning.

Chapter 8, by H.-P. Huang and J.-C. Jeng, focuses on identifying simple models meaningful for PID control based on step and relay tests on the plant. The process reaction curve method and graphical means for obtaining model parameters for first- and second-order models with deadtime are discussed, as well as means for obtaining these models from relay feedback. Chapter 8 is the only chapter in the text that describes the use of the internal model control (IMC) design procedure obtaining PID tuning rules from simple models. The chapter concludes with an assessment of optimal PI/PID control performance contrasting integral absolute error (IAE) norm criteria and rise time.

Chapter 9, by K.S. Tang, G.R. Chen, K.F. Man, and S. Kwong, describes fuzzy logic and genetic algorithms for PID tuning. The authors' motivation for these approaches is the premise that, in problems with large delays, parameter variations, and nonlinearities, conventional PID controllers often fail. This chapter is one of the few chapters that address the use of PID control in a nonlinear plant environment. An example problem involving a simple nonlinear plant model is examined. It would have been helpful to show a comparison to some well-established technique for designing nonlinear PID controllers, for instance, gain scheduling [1], to justify the effort involved in implementing a fuzzy/genetic algorithm approach. The chapter concludes by referring the reader to a series of industrial applications of fuzzy PID control.

Chapter 10, by A. Sanchez, M.R. Katebi, and M.A. Johnson, focuses on subspace methods for restricted-complexity controller design from closed-loop data. Since subspace methods can be used to obtain models for multivariable systems without requiring much a priori knowledge of the system structure, these methods have significant appeal. A series of case studies involving simulation of an activated sludge wastewater treatment plant are presented. To my disappointment, the identification data used to generate the modeling results is never shown. Given the importance of data quality in identification problems, particularly under closed-loop conditions, I would have preferred a discussion regarding the information content required for success of the algorithm in lieu of the emphasis on parameter estimation.

Chapters 11–13, comprising the final section of the book, focus on parametric design methods that assume that a transfer function model is available at the onset of the design procedure. Chapter 11, by Q.C. Wang, Yong Zhang, and Yu Zhang, focuses on the design of PID controllers for multivariable systems. Both fully decentralized PID controllers and PID controllers with decoupler designs are presented, with the latter problem posing challenges for systems possessing nonminimum phase behavior. Chapter 12 deals with restricted-complexity-structure optimal control. This chapter is authored by P. Martin, M.J. Grimble, D. Greenwood, and M.A. Johnson. The idea here is to design controllers that minimize an LQG objective but conform to the PID structure. Both single-loop and multivariable algorithms are discussed.

The final chapter, Chapter 13, coauthored by M.H. Moradi, M.A. Johnson, and M.R. Katebi, addresses the topic of predictive PID controllers. In this chapter, the goal is to establish links between PID control design and predictive control methods through two classes of methods. The first half of the chapter is devoted to Smith-predictorlike approaches in which prediction of delayed effects is incorporated into the feedback loop to create an enhanced PID-like control structure. The second approach is to design a bank of PID controllers whose manipulated variable responses are matched by an approximation problem to those of a generalized predictive controller (GPC). In all of these multivariable approaches, the design procedures are fairly elaborate, and considering how widespread predictive control has become (with some vendors now offering implementations on process-connected devices where PID control was previously the only option), it seems that there is a diminishing practical incentive for exploring these types of problems. Nonetheless, it is useful for the control community to be aware of these techniques and to recognize that there exist circumstances under which PID-like controllers can mimic the performance of more sophisticated predictive control algorithms.

EVALUATION AND CONCLUSIONS

As an edited text with a large number of individual contributors, it is somewhat of a challenge to make broad statements regarding the effectiveness of this book. In general, the book is well organized and provides a wealth of new information. At first glance, it does not come across as a highly pedantic text. While it is not intended to be a standalone reference for "all things that are PID control," I do believe that the book serves a useful role in informing the control community of the variety of methods and approaches for PID controller tuning that are currently available. Individuals and research groups that devote significant attention to PID design topics should seriously consider adding this text to their reference collection.

Shortcomings of the book come at various levels. Despite the plethora and diversity of methods that are presented, the bulk of these methods are geared toward circumstances in which the magnitude of noise and disturbances experienced by the plant during controller tuning is low. I would have preferred to see greater focus on identification and PID design methods that address process conditions involving significant load disturbances and noise, situations that are often found in industrial practice. Alternatively, some of the methods that are presented, such as the restricted complexity subspace identification approach in Chapter 10, could have been made stronger by using simulations or case studies to illustrate how these methods work under demanding experimental conditions.

The biggest shortcoming of the text is that very little mention is made of available software or computing resources that can be accessed to implement the techniques presented in the various chapters. While dedicated sections describing algorithms are included throughout the book, these sections limit the usefulness of the text as a reference and study guide. Considering the large number of simulated examples and the obvious use of MATLAB to generate solutions in these cases, it is a pity that the corresponding .m and .mdl files are not made available to the readers. A great number of the methods, particularly those presented in the final chapters, are quite complex, and even a basic implementation for evaluation purposes would entail significant effort.

Also disappointing was the lack of solid references on several subjects. For example, the discussion of antiwindup techniques, an important practical consideration in PID control implementation, is rather superficial. Even though PID tuning relying on IMC is the basis for the methods presented in Chapter 8, none of the primary references for this work are cited in the chapter. I also found throughout the text a problem that I usually call to the attention of my undergraduate students when documenting and presenting control results; in the case studies for many chapters, only the controlled variable response is presented, while *both* manipulated and controlled variable responses should be included to fully assess a control system's performance.

One also sees a fair amount of repetition of background material between the chapters, which could have been reduced by better coordination among the authors. Similarly, the book could have benefitted from a textwide analysis of benchmark problems whose solution would then be consistently illustrated among the various chapters. Such an approach would have provided readers with a systematic basis for evaluating the benefits and drawbacks of the various methods presented. Despite these shortcomings, the book represents a welcome addition to the control field and should be considered by any serious researcher in the field of PID control.

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