Book Review

Practical PID Control—Antonio Visioli (Springer-Verlag, 2006). *Reviewed by Heikki N. Koivo*

I. Background

"There are eight million stories in The Naked City. This has been one of them." The famous quote from the Naked City TV-series comes to mind, when one opens Visioli's book on PID (Proportional-Integral-Derivative) control. Do we not have enough PID control books and enough knowledge of this most widely used controller? A gut feeling says yes, but the correct answer is no. This both Visioli's book and I try to justify.

Let's look at the other side of the coin. Many studies suggest that of all the controllers in industrial process control, PID (or PI) controllers are used in 95–97% of the cases. If one considers numbers of PID controllers around us, then the figure is amazing. It is not only in industrial processes and manufacturing plants where they are used, but in electric power generation and transmission, gas and water distribution systems, building automation, automobiles, airplanes, trains, elevators—the list is endless. Then taking into account embedded systems, such as computer disk drives or cellular phones and networks, we are not talking about millions of PID controllers, but the figure is over a billion. The question then is, why do we not have more PID textbooks available?

What is there in the PID controller that makes it so useful? A PID controller has all the key ingredients that a control function needs. The proportional P-part reacts immediately to the error, the integral (I) part remembers the past errors, summing up even small ones to make the eventual correction, and the derivative D-part predicts the future in order to rectify the error. What else is needed? It is all there! In a small neighborhood of the operating point, you can hardly do better. Another extremely useful feature is its simplicity. The KISS (keep it simple stupid) principle is followed to the letter. In commissioning or during operation of the plant, the controller has to be tuned periodically. The fewer parameters to tune, the better off you are.

The claims that PID controllers will be replaced as low level controllers with some others, say neural network controllers, are nonsensical. Of course, there are situations where more sophisticated controllers are needed, but even these have the same basic features as the PID controller, with a better ability to handle the system nonlinearities. More complicated controllers, like model predictive controllers (MPC), tend to have more parameters making their tuning harder and more time-consuming. To cope with nonlinearities, the basic PID controller can also be augmented with gain scheduling or adaptive features to better handle more complex phenomena.

There are a number of new technological developments that require us to have a fresh look at PID controllers and their tuning. These include control via the internet and wireless control. PID controllers in the networked case require treatment of asynchronous data and use of insufficient information, such as missing measurements. Ever increasing numbers of embedded systems force us once more to consider problems arising from limited world length. Although these issues are not addressed in Visioli's book, it is a welcome addition to the PID control literature, which has been increasing at a surprising rate since 1980's.

The reviewer is with the Helsinki University of Technology, Espoo 02015 TKK, Finland (e-mail: heikki.koivo@hut.fi).

Digital Object Identifier 10.1109/TAC.2008.920854

II. The Book

The book consists of nine chapters. At the end, there is a short Appendix describing two laboratory equipment processes used to demonstrate the efficiency of the algorithms. The processes are a double tank process for level control experiments and a small laboratory scale oven for temperature control. Most of the chapters are structured as follows: First the problem is posed and a number of approaches to solve the problem are explained. Then the results are illustrated with simulations using different transfer functions. Finally the developed concepts are verified with the two laboratory processes. Such structuring helps the reader to bridge over from one chapter to another.

Chapter 1 reviews the basics of the continuous PID controller. This introductory chapter is well-written and concise. The three actions of the PID controller are first explained. Then the different structures of the basic PID control law together with its modifications are reviewed. Digital implementation and tuning issue are also briefly explained. For the rest of the chapters, continuous time is used throughout the book. The only exceptions, where discrete-time systems are employed instead, are a brief discussion of noncausal feedforward action in Chapter 5 and a portion of Chapter 8, where the performance assessment is examined in discrete time. This is a pity, because the book would have benefited significantly, if the discrete-time case would have been addressed more thoroughly.

Chapter 2 is devoted to derivative filter design. The derivative part in the PID controller cannot be perfectly realized, so approximate filters are used instead. In practice this adds one extra parameter to the overall design of the PID controller, meaning that four parameters instead of three must be determined. Visioli states that the derivative part of the PID controller is seldom used in practice. This is true in process control, but not in motion control. In servo problems the derivative controller is essential. Indeed, the treatment of motion control is practically nonexistent in the book, but the bias towards process control issues is evident also in the other treatises on PID control.

Chapter 3 discusses the well-known practical problem of the PID controller, anti-windup in the integral part. The reason for this phenomenon is the saturation of the actuator. The PID controller assumes the overall system to behave linearly all the time, so integration will proceed even when the actuator cannot provide more power. This results in an oscillatory behavior. A number of up-to-date anti-windup techniques are reviewed and compared with each other both by simulation and experimentally. The discussion is thorough and many of the recent anti-windup techniques are presented.

Chapters 4 and 5 examine feedforward strategies. In Chapter 4 the context is set-point weighting. PID controllers are often tuned based only on open-loop step responses. Reduction of load disturbance effects cannot be handled well, and vice versa. To take into account the effect of disturbances the weighting of the set-point signal in the P-part is proposed. This results in a two-degree-of-freedom structure. Both constant and variable set-point weighting are presented. A detour to fuzzy set-point weighting is also made. Chapter 5 continues with a more extensive coverage of feedforward control especially in the set-point following task. Both causal and noncausal feedforward actions are described. The presentation is based on continuous time, except for one section: noncausal feedfoward action—discrete-time case. The chapter concludes with a short coverage of the feedforward principle in disturbance rejection. The author himself has made a number of contributions to the topic.

Chapter 6 introduces a novel, topical issue: plug and control. Since the early 1990's the plug and play concept has been introduced in the context of computers and devices connected to them. Plug and control means that after the controller or controller block is connected to the system, it is automatically tuned to work properly. Chapter 6 covers some of the plug and control strategies in the case of temperature control. It seems that this convenient and useful concept will be developed in the future for a much wider class of applications.

Chapter 7 reviews identification and model reduction techniques in the setting of PID control design. Here, although one might expect a discussion of the discrete-time case, surprisingly everything is only done in continuous time. Both the open-loop and closed-loop cases are covered. The chapter concludes with the design of a PID controller when a high-order model is available.

Another important, fairly new concept, performance assessment, is treated in Chapter 8. Modern industrial plants have hundreds or even thousands of continuous control loops. If critical control loops are poorly tuned, the outputs will oscillate and create problems in the latter stages of the process or even in the final product quality variables. Automatic performance monitoring means have recently been developed to better cope with the overall control performance. These issues are addressed in Chapter 8. First, stochastic performance monitoring is reviewed and then deterministic. In the stochastic case the ability to handle stochastic disturbances is the main issue. The presentation is made in the discrete time case. In the deterministic case, set-point following and load disturbance reduction are the key elements. Here the discussion is switched to continuous time. The emphasis in the chapter is on the deterministic case, which the author feels to be more important.

The last chapter in the book, Chapter 9, surveys other control structures, where PID controllers are used. These include cascade and ratio control. Again the author does a nice job of reviewing the latest research results in these two areas.

III. Comments

Visioli's book covers the newest techniques of PID controllers in many areas. These are clearly explained and vividly demonstrated. It is evident that Visioli himself has contributed significantly to many of the topics covered. The book has also an excellent list of references to recent literature.

Some criticism is also in order. At some points of the book the author uses concepts that are not well-covered in the text. These include genetic algorithms in connection with optimization and fuzzy logic approaches. The methods come as a surprise to the reader, because no detailed material is provided about them. An appropriate way would have been to discuss these, e.g., in the Appendices. Now, only references are given.

Another problem is the use of optimization methods in various chapters. For example, the author refers to ISE or ITAE criteria without specifying them. In addition to the genetic algorithm, the simplex method is quoted as a search method. The reader is at a loss. Neither of these well-known methods and concepts are discussed in detail nor justified. Apparently the simplex method and the genetic algorithm are used because gradient information is not available when the classical ISE or ITAE criteria are applied. In fact, the whole standard optimization methodology is treated superficially. 'Practical' is a very demanding adjective in the title of the book. Personally I consider it to be misleading, because the book is not meant for a practicing control engineer, but rather for an academic audience. For a control engineer working in industry, there are far too many detailed, long analytical derivations of various algorithms and little straightforward advice of how to use these in practice.

The books on PID controllers in general, as well as the one considered here, emphasize various sophisticated tuning methods for PID controllers. Here and there it is argued that the operator tunes the PID controllers. This, in general, is not true in most of the process industry. Typically, the operators are too busy to do the tuning. It is rather the responsibility of the maintenance group. Therefore, the problem of tuning PID controllers is often more of an organizational problem than a technical problem, because the level of sophistication in the maintenance group may not be very high. Furthermore, the first priority of the maintenance group is to worry about the runnability and availability of the plant. Therefore the tuning of PID controllers has a rather low priority. Often, PID controllers are only retuned when components are changed due to malfunction, and the job of retuning of the controllers may also be completely outsourced.

A minor annoyance in the book is that almost on every other page a grammatical error or misprint occurs. If this would happen only once in-a-while, the reader would not mind, but too much is too much. The editorial task really requires more work. Some of the items that this reviewer would have liked to see are issues of motion control, multivariable PID control, perhaps fuzzy PID control, and in general, more emphasis on the discrete-time approach.

Apparently Visioli has used the seminal work of Åström and Hägglund [1] (and now [2] by the same authors) as a model for his book, limiting the scope slightly. In certain areas he opens doors to new ideas better than [1], but certainly [1] gives a more comprehensive, detailed look at PID control. In any case, Visioli should be congratulated for his efforts and novel ways of treating PID control.

References

[1] K. J. Åström and T. Hägglund, *PID Controllers: Theory, Design and Tuning*. Research Triangle Park, NC: ISA Press, 1995.

[2] K. J. Åström and T. Hägglund, *Advanced PID Control*. Research Triangle Park, NC: ISA Press, 2006.