Applied Digital Control—Theory, Design and Implementation*

R. J. Leigh

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ACCORDING TO the introduction, 'the book aims to establish a strong theoretical background to support applications, material relevant to the design and implementation of digital control systems'. It is meant for 'industrial engineers and scientists as well as for students on formal courses'.

A first scan of the contents of the book shows that there is a lot of technology in the book. Examples of industrial control systems, such as the Honeywell TDC 3000 system are given in the chapter on commercially available distributed control systems and in several case studies. The preface to the second edition indicates that the book has been updated to include present technology. Of course with so much attention on realizations this update will be frequently necessary, because the technology is rapidly changing. This also implies that this information will be outdated in a few years.

When emphasis is given to realizations there is always a choice to be made, i.e. whether to concentrate on general principles, or to introduce specific technical possibilities. The latter choice will help the reader in the short term, by providing information that can immediately be used and applied in a project. The first choice may be more valuable in the long run. The book chooses, to a certain extent, to provide a lot of information on commercially available systems and solutions based on specific technology. A reader searching for this kind of information can benefit from studying the book. If you are looking for a book that gives a firm foundation of modern digital control, there are better choices available.

After reading more carefully, the weight given to the various topics seems poorly balanced. There is a chapter on advanced topics (Chapter 12: Adaptive and Robust Control). In 38 pages, too many subjects are only briefly mentioned, rather than covered in depth. It is questionable whether this is of any use.

In Chapter 8, pole placing by means of state feedback is treated, but practical design methods, such as those given by Ackermann are missing. Pole placing by means of output feedback is not described. The Ricatti equation in the section on optimal state feedback is not derived and no reference is made to the relevant literature.

On the other hand, there are 22 pages on quantization effects in addition to a chapter of 30 pages about hardware systems for implementation that mainly deals with A/D- and D/A-conversion. This observation holds for other topics.

In total the book contains 12 chapters. After a five page introduction to the key features of digital control the following chapters are:

- 2—Discrete time signals (pp. 6–22: introduces sampling);
- 3—Z-transform techniques (pp. 23–68: introduction of the z-transform, assuming knowledge of Fourier and Laplace, relation z-plane and s-plane, difference equations);

- 4—Methods of analysis and design (pp. 69–110: root locus, frequency response (w -transformation), stability tests);
- 5—Digital control algorithms (pp. 111–197: various approaches to the design of digital controllers: continuous modelling, discrete controller design, transformation of continuous-time controllers to discrete controllers, dead beat, including modified versions, use of hill climbing for controller tuning, w' -domain (why here w' and in Chapter 4 w ?), design realizations such as parallel method, factorization, choice of sampling interval, word length effects. Recent developments such as the delta-operator are not mentioned. Emphasis is on translation of continuous-time designs to discrete algorithms, less on a complete digital design);
- 6—Elements in the control loop (pp. 198–228: sensors, actuators, A/D- and D/A-converters);
- 7—Tutorial case histories (pp. 229–250: some typical examples of industrial control problems, including realizations);
- 8—State variable techniques (pp. 257–335: introduction to (discrete) state space description, short introduction to optimal control, state reconstruction and Kalman filtering);
- 9—Control of large scale systems (pp. 336–360: system decomposition, hierarchical control, multilayer control and optimization);
- 10—Control systems implementation and integration (pp. 361–384: interconnection of computer systems, reliability aspects);
- 11—Commercially available control systems and their industrial application (pp. 385–451);
- 12—Adaptive and robust control (pp. 452–490: almost nothing of too many modern topics).

The order of the subjects is not always logical. Hardware and even product aspects (Chapters 6, 7, 10 and 11) are between the theoretical parts of the book (Chapters 1–5, 8, 9 and 12). This observation not only holds for complete chapters but also for details. Practical remarks are mixed with more systematic treatments, without a clear relation between the two.

On the same page different terms are used for the same network (lag network and dipole addition) without pointing out the relation between the two or indicating a historic background for using such different terms.

In the theory the w -transformation is treated, while in the applications the w' -transformation is used. The latter is said to be better than the translated continuous design, but unfortunately the advantage of using it is not shown. The use of the Nichols chart is mentioned as useful, but not discussed or clarified by an example. The problem of ringing poles is mentioned. A 'crude solution' is given, but the effect is not further illustrated.

In Chapter 4 discretization methods are described, where it is found that compared to backward difference approximation and trapezoidal approximation, the forward difference approximation gives the worst solution. Nevertheless in Chapter 5 the last rule is used to discretize a PID controller, without indicating why this rule should be preferred.

The sampling interval considerations are treated in the design chapter (5), while similar considerations already played a role before.

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In the book the philosophy behind the design of (industrial) controllers is: keep it simple. In an industrial environment, especially in systems where only poor models are available PID controllers are advocated as the best choice. The advantages of applying more advanced controllers could get more attention, but such a view is described as 'an over-optimistic view of academic sources'. This indicates again the scope of the author, to provide information for practice-oriented engineers.

The book contains a lot of exercises. Unfortunately there are no answers provided. The figures are in many cases too far from the related text. Often several pages *before* they are referred to. The index is poor. It is too short and contains incorrect page numbers. In the bibliographic references I missed some well-known reference books on digital control, which could be of help to the reader who requires a more solid base for the control techniques which are mentioned only too briefly in this book.

The overall conclusion is that the book is mainly useful for people who want to know about practical aspects of digital control on an instrumentation level. I would not recommend it for academic courses, because it lacks enough depth in the description of more advanced algorithms.

About the reviewer

Job van Amerongen was born on 22 November 1946 in Veenendaal, The Netherlands. He obtained his Master's

degree in electrical engineering at Delft University of Technology in 1971 and obtained a Ph.D. degree in 1982. From 1971 to 1973 he did his military service as an officer in the Royal Netherlands Navy. From 1973 to 1987 he was a (senior) scientific staff member and an associate professor at the Control Laboratory of the Department of Electrical Engineering of Delft University of Technology, where he worked on applications of modern control theory, especially model reference adaptive control, in ship control systems and electrical power production systems.

In 1987 he became professor in control engineering in the Department of Electrical Engineering at the University of Twente. His current research interests are applications of modern control theory, especially adaptive and intelligent control, in mechatronic systems. As head of the control laboratory he is also involved in the research of modelling and simulation of dynamical systems and in real-time parallel computing. Since 1989 he is also director of the Mechatronics Research Centre, Twente, a co-operation of four departments of the University of Twente. Since 1994 he is Dean of the Department of Electrical Engineering. He is Chairman of the Dutch Foundation for Measurement and Control Technology.

He is (co-)author of many papers on adaptive control systems, automatic steering of ships and of a book on adaptive control systems. He is also author of two courses on systems and control of the Dutch Open University.

Simulation and Modelling of Continuous Systems—A Case Study Approach*

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MANY DISCIPLINES use simulation—or to be more precise—computer simulation for analysing and designing systems. Among these, control engineering is one of those disciplines which discovered quite early, i.e. in those early days where analogue computation was synonymous with simulation—the possibilities and advantages offered by simulation. During the last decade or two, digital simulation became comparable with respect to speed and more advantageous than analogue/hybrid hardware with respect to ease of programming (despite aids for automatic problem set-up and automatic scaling which actually worked) and particularly, with respect to problem size and accuracy. Last, but not least, digital hardware and to some extent also software became cheap and simulation of small and medium sized problems can now be performed comfortably on PCs.

As a consequence of these developments, analogue or analogue/hybrid equipment is used only in special situations, e.g. for time-critical tasks or for studying the influence of discretization on a continuous-time system, or to compare a digital controller with its continuous (analogue) counterpart or, for training purposes where it still has its merits (e.g. for teaching the difference between 'continuous' and 'discrete' or, the physical meaning and consequences of sampling).

Nowadays, sufficient software support for simulation is available which allows not only for convenient problem description and computations, but provides various tools for

presentation of the results. These languages and tools are designed as general purpose tools and allow for understanding the main features within a short time. Consequently, a relative diverse community of scientists and engineers can use simulation for problem solving. On the other hand, real-life problems and in particular real-life problems of automatic control, demand a deeper insight into simulation and careful modelling.

As mentioned, simulation aids are designed to serve a broad community of scientists and engineers. Consequently, simulation languages, whether or not they are designed according to the CSSL-standard, do not provide all the features and devices a control engineer is familiar with and would like to have at his disposal. Therefore, it is not surprising that in the early years of digital simulation many simulation tools and languages were developed by control engineers. This has changed somewhat and special purpose environments and tool boxes for existing simulation languages are developed by and/or for control engineers, e.g. optimization environments like OPTIM and GOMA (Breitenacker *et al.*, 1993). Moreover, today's tools (e.g. CTRL-C or MATLAB) are available which are much more flexible than the CSSL-type simulation languages and which strongly support a mixed environment of different analysis techniques including simulation as one of them.

Modelling aids, especially aids for graphical modelling such as MODEL-C for CTRL-C, and the possibility of modular and/or hierarchical modelling are of importance in the field of automatic control (Breitenacker *et al.*, 1993; Cellier, 1991). Unfortunately these approaches frequently lead to so-called algebraic loops, i.e. to implicit differential equations or to differential-algebraic equations. Both types cannot be handled directly by standard integration routines. Sometimes, such loops can be solved automatically, although this is only possible via skilled programming or by performing it numerically. As systems to be investigated become more complex, there are situations where special programs have to

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