Nichtlineare und adaptive Regelungssysteme*

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DURING THE last two decades the literature on systems and control has shown an increasing interest in the theoretical and practical developments in the areas of nonlinear systems and adaptive control theory. The book under review, which in English would be entitled *Nonlinear and Adaptive Control Systems*, is possibly one of the first treatises combining these two research areas.

Nichtlineare und adaptive Regelungssysteme is intended for graduate and research students in mechanical and electrical engineering departments. As the title already announces, the contents of the book are essentially split into two parts; namely Chapters 1–4, dealing with nonlinear systems, and Chapter 5, where adaptive systems are treated. Knowledge of linear control theory is a prerequisite for reading the book. Next, a brief description of the contents of the book is given. The first chapter contains a brief introduction to nonlinear systems together with some classical examples of such systems. In Chapter 2 a discussion about periodic orbits of nonlinear systems is given. The stability of these orbits is studied via the well-known harmonic balance method. In Chapter 3 the stability of nonlinear input–output systems is studied via functional analytic methods and contains in particular a classical circle criterion for input–output systems. Then the authors describe in Chapter 4 the analysis and synthesis of nonlinear systems in state space form. The main emphasis is again on stability (and stability-improvement) and therefore the first and second methods of Lyapunov are explained. The last chapter centers around adaptive (control) systems. Two standard approaches from adaptive control theory are investigated in detail, namely the Model Reference Adaptive System approach and the Self Tuning Regulator. Finally, the book has eight appendices on successively differential equations, Fourier and Laplace transformations, functional analysis, observer design, elementary stochastics, parameter estimation, dissipativity and hyperstability of dynamical systems. Throughout the book various well-chosen worked examples illustrate the described techniques and shortcomings.

Nichtlineare und adaptive Regelungssysteme fits well in the present day German control literature. The results are clearly presented and well motivated. However, where possible reference is made to papers and textbooks in German, thereby ignoring their sometimes more standard English counterparts, as for instance *Stability Theory of Dynamical Systems* (Willems, 1970) or *Finite Dimensional Linear Systems* (Brockett, 1970).

The book treats very fashionable topics from the systems and control literature. However, it does not reflect the present status of these areas. Indeed it is more difficult to characterize (local) controllability and observability for a nonlinear system than for a linear system, but there are

certainly some rather simple rank tests available; see e.g. Hermann and Krener (1977). In fact, it is not exaggerating to say that the modern *mathematical* advances in nonlinear control theory [see for instance the proceedings of Fliess and Hazewinkel (1986) and Byrnes and Lindquist (1986)] are completely missing. Once again, this seems to give evidence for the gap between theory and “practice” in control engineering, cf. Bell (1988).

Stability (and stabilization) is an important issue of the book under review. The authors therefore clearly emphasize the theory on Lyapunov-functions together with various ramifications (Krasovski, Zubov, etc.). Nevertheless the authors do not discuss the celebrated invariance principle due to LaSalle [see LaSalle and Lefschetz (1961)]. I feel this is a serious omission. The point is that in many adaptive control schemes, convergence is studied by means of suitably selected Lyapunov functions, and the parameter-convergence is related to the existence or nonexistence of nontrivial invariant sets. The motivating example of an adaptive controller for a first order system on p. 321 forms a perfect illustration of this point.

Altogether the book, which is well written, does not give a complete up-to-date state of the arts of nonlinear and adaptive control, but merely serves as a “classical” engineering textbook in this area.

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About the reviewer

Henk Nijmeijer received both his university degree and doctorate in Mathematics from the University of Groningen, The Netherlands in 1979 and 1983, respectively. After spending three years at the Center for Mathematics and Computer Science (CWI) in Amsterdam he took a research/teaching position at the Department of Applied Mathematics of the Twente University of Technology, Enschede, The Netherlands in 1983. His main research interest lies in the area of nonlinear and linear geometric control theory.

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