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Nonlinear Identification and Control: A Neural Network Approach by G.P. Liu, Springer, New York, 2001, 210 pp., Euro 79.95, ISBN 1-85233-342-1. Reviewed by Victor M. Becerra, University of Reading, U.K.

The field of neural networks is vast, with many different known network architectures and training algorithms. This monograph deals with the application of neural networks to nonlinear identification and control. The book focuses on radial basis functions of the Gaussian type and Volterra polynomial basis functions, with a chapter based on wavelet networks. It introduces neural networks and provides details of different architectures. It also provides background on learning and approximation theory, including some classical training algorithms such as backpropagation.

One of the central neural network paradigms used in the book, which is presented quite convincingly by the author, is the variable-structure neural network, wherein the number of basis functions of the network can be increased or reduced over time to avoid overfitting or underfitting and considering the novelty of the observations. Techniques based on Lyapunov stability theory are used to guarantee the stability of estimation. The variable-structure networks based on radial basis functions are introduced in chapter 2, together with a method for sequential identification for continuous-time nonlinear systems. These networks are used later in the book to derive a continuous-time adaptive control scheme with guaranteed stability. The book also presents a recursive identification scheme for nonlinear discrete time systems based on Volterra polynomial basis function networks, with techniques for offline initial structure selection and online structural adaptation of the networks.

In nonlinear system identification, multiple objectives usually need to be considered (for example, approximation accuracy and model complexity). These multiple objectives are often conflicting, so some tradeoff is inevitable. The book presents methods based on genetic algorithms and multiobjective optimization techniques for model selection and parameter estimation.

In recent years, wavelet functions have become an important tool for localized function approximation at different scales, and they can be viewed as a basis for representing functions. Wavelet networks, which are inspired by feedforward networks, have found application in nonlinear system identification. The book introduces a wavelet network nonlinear identification scheme. Once again, techniques are provided to adapt the structure of the network over time and also to guarantee the stability of the learning algorithms.

A nonlinear predictive control scheme based on affine neural network predictors is also presented. This scheme avoids the use of nonlinear programming techniques and therefore is easy to implement and computationally inexpensive, but loses appeal by not considering inequality constraints on inputs, states, or outputs. The neural network predictors are adjusted in structure and parameters using an algorithm that guarantees weight and estimation error convergence. However, the stability of the closed-loop system is not guaranteed.

Variable-structure control based on sliding modes is a well-known nonlinear control technique that has attractive robustness properties. A variable-structure control technique based on neural-network-based affine predictors is introduced in the book. The technique involves adjustable weight parameters and network structure and exhibits guaranteed convergence of the weights and estimation errors.

The book is the result of many years of research and publications by Dr. Liu. Overall, it is well written and presented and will be useful for researchers in the field of nonlinear identification and control. Methods are illustrated with relevant simulation examples, and the final chapter presents a simulated and experimental case study based on a combustion process wherein a network with sinusoidal basis functions is used as an output predictor. Unfortunately, the experimental case study did not involve the identification and control techniques presented in previous chapters, particularly those techniques based on variable-structure networks. The book would have benefited from a more careful writing of the introductory section of some of the chapters to avoid redundancies. Also unfortunate is that Lyapunov's second stability theorem for continuous-time systems is presented for the first time in chapter 6, while Lyapunov's second method is used previously, without introduction and for both continuous- and discrete-time systems, in chapters 2, 3, and 5. Nevertheless, the book will be a good addition to the libraries of those interested in the subject.

The Fractional Fourier Transform: With Applications in Optics and Signal Processing by Haldun M. Ozaktas, Zeev Zalevsky, and M. Alper Kutay. Wiley, New York, 2001, 532 pp., $105, ISBN 0471-96346-1. Reviewed by Mike Meade, Open University, U.K.

The fractional Fourier transform is a generalization of the ordinary Fourier transform with order parameter a. If a

varies continuously from 0 to 1, then the transform evolves smoothly from the original function to the ordinary Fourier transform in the same way that the diffraction pattern of an aperture evolves continuously from its near-field to its far-field form.

This observation provides the starting point for this remarkable book in which the authors set out to explore the role of fractional Fourier transforms in Fourier optics and optical information processing, covering Fresnel diffraction, optical beam synthesis and propagation, spherical mirror resonators, optical systems design, and signal detection.

Although the central chapters deal at length with optical topics and applications, the material here is strictly segregated from the greater part of the book, which is devoted to wider aspects of the fractional transform and its mathematical background. The treatment of mathematical preliminaries in the opening chapters is thorough and virtually self-complete in its exposition of signals, systems, and transformations, Wigner distributions, and linear canonical transforms. The range of topics covered and the depth of treatment afforded provides essential underpinning for chapter 4, where the reader is introduced to no fewer than six definitions of the fractional Fourier transform, supplemented by a similar number of distinct but nonequivalent definitions proposed by other authors.

The fractional Fourier transform of a function $f(u)$ exists under the same conditions for which its Fourier transform exists. However, closed-form expressions for the fractional Fourier transform can be derived for only a handful of functions, most notably in the case of chirp functions (degenerate and limiting forms of which include harmonic functions and delta functions). Further discussion involving sets of sampled data and the definition of the discrete fractional Fourier transform is deferred to chapter 6, following a brief description of so-called time-order and space-order representations in chapter 5. The authors acknowledge that research on the DfFT (or dfFt) is in a state of flux, with no report as yet of a computationally efficient routine akin to the FFT. For this reason, particular importance is attached to an algorithm that can compute an N-point transform in terms of the N samples of $f(u)$ in $O(N \log N)$ time.

The authors justifiably claim that the three central chapters (7, 8, and 9) can be viewed as a short, self-contained course on advanced Fourier optics emphasizing space-frequency concepts. To the authors' further credit, this material can be omitted by those wishing to proceed directly to the final two chapters, which deal with signal and image processing applications of the fractional transform. Chapter 10 shows that the theory of optimal Wiener filtering in the ordinary Fourier domain can be generalized to optimal filtering in fractional domains with the potential (for some scenarios, at least) of achieving smaller signal recovery errors at practically no additional cost. In a similar vein, chapter 11 discusses applications of the fractional transform to matched filtering, detection, and pattern recognition. Here, as elsewhere, the presentation is greatly enhanced by the inclusion of historical and bibliographical notes linked to two extensive bibliographies, the first devoted to the fractional Fourier transform and its applications and the second to other cited works.

The authors have succeeded in producing a text accessible to a cross-disciplinary graduate audience. Its publication will surely have a significant impact in those areas of mathematics, science, and engineering where Fourier transforms and related concepts are used.

Fixed Interval Smoothing for State Space Models by Howard L. Weinert, Kluwer, Boston, MA, 2001, 136 pp., $98.00, ISBN 0-7923-7299-9. Reviewed by Pavlos K. Giannakopoulos, Greek Ministry of Finance.

This monograph addresses the fixed-interval smoothing problem for linear, finite-dimensional, time-invariant state-space models. The author's approach is based on the properties of complementary models—those that span the space of random variables orthogonal to the linear subspace spanned by the observations process. The concept of complementary models was introduced by Weinert and Desai [1] and has proven to be a very useful tool for understanding the problem of smoothing in state-space models.

The book is divided into five chapters. Chapter 1 briefly describes four types of state-space models: the basic discrete-time model, the interpolated discrete-time model, and the continuous-time and discrete two-point boundary value models. These models are used in subsequent chapters for presentation of the smoothing algorithms. The chapter ends with a brief description of the fixed-interval smoothing problem. Chapter 2 introduces the concept of complementary models, which are derived for the basic, the interpolated discrete-time, and the continuous-time models. These boundary value systems constitute the basis from which derive all the recursive smoothing algorithms mentioned in the subsequent chapters. In the first three sections of chapter 3, the author presents well-known smoothing algorithms, beginning with a complementary state-space model that runs backward in time, from which is derived a backward-forward smoother. This is followed by the derivation of two forward-backward algorithms in the second section and the derivation of the two-filter smoothing formulas in the third section, which ends with a comparison of the four types of algorithms in terms of efficiency and computational complexity. The chapter continues with square root implementations of the previous four basic smoothing algorithms and ends with the interpolated discrete-time case and its square root implementations. Chapter 4 deals with the continuous-time smoothing formulas for the four basic algorithms discussed in the previous chapter. In Chapter 5, the complementary model for discrete-time, two-point boundary value systems is derived, with the backward-forward smoother being the only one presented, as it is the most efficient in terms of implementation complexity. The equations of the smoother and the corresponding errors are also derived. The book ends with an annotated bibliography.

The book presupposes that the reader is reasonably familiar with basic concepts in estimation of random processes, linear systems, vector spaces, and matrix theory. It is written in research monograph form, summarizing many of the author's results and publications. The chapters are well written, providing the reader with all necessary references to relevant bibliography, thus offering ample opportunity for further exploration on the algorithms covered in the book. Additionally, new material on interpolation, fast square root implementations, and boundary value models is presented. The notation is simple, the presentation clear, and the derivation of the algorithms easy to follow.

In conclusion, the book provides an integrated approach to the fixed-interval smoothing problem and should be very useful to researchers who work in smoothing problems, as well as to practicing engineers who are involved in this field and need to decide on an appropriate smoothing algorithm.

Reference

[1] H.L. Weinert and U.B. Desai, "On complementary models and fixed-interval smoothing," *IEEE Trans. Automat. Contr.*, vol. AC-26, pp. 863-867, 1981.