linear shift invariant systems. It subsequently discusses methods for sampling two-dimensional continuous signals and compares several stategies such as rectangular and hexagonal sampling.

Chapter 2 is an excellent introduction to the multidimensional discrete and fast Fourier transforms and concludes with a section on the interrelationship between the M-dimensional and the one-dimensional DFT's.

Chapter 3 deals with design and implementation techniques for two-dimensional finite impulse responce (FIR) filters. Various techniques such as windowing, optimal least squares design, and transformations are discussed together with several implementation techniques such as direct, block convolutions, and DFT. The implementation and design of hexagonal FIR filters concludes this chapter.

Chapters 4 and 5 discuss multidimensional recursive systems and the design and implementation of two dimensional IIR filters. Chapter 4 deals with finite difference equations, multidimensional z-transforms, the stability of recursive systems and the two-dimensional complex cepstrum. Chapter 5 deals with IIR filter implementation and design techniques and contains a brief discussion on filter stabilization.

Chapter 6 discusses the use of multidimensional signal processing in the context of signals received by an array of sensors. Beamforming as a linear filtering approach to the problem of determining the strength and direction of propagating energy is discussed in the first part of the chapter. The second part of the same chapter focuses on multidimensional spectral estimation methods such as high resolution, all-pole modeling, and maximum entropy.

Chapter 7, entitled "Inverse Problems," deals with the problem of image reconstruction from limited measurements and *a priori* information. The first part of this chapter deals with constrained iterative signal restoration and is a valuable introduction to the field of image restoration. The second part of this chapter introduces the concepts of signal reconstruction from a limited number of projections mainly from the computer-assisted tomography field and is equally informative.

In summary, I found this book well written and consistent with the authors' claim: a treatment of multidimensional signals as opposed to image processing only. A worthwhile effort has been spent on bringing out the important similarities and differences between the one- and two-dimensional cases. In this context I found this text a valuable addition to my personal library and because a different view than the majority of two-dimensional DSP books is presented, I strongly recommend it to anybody interested in the multidimensional signal processing field in general or an introduction to the image, seismic, CAT, or array processing areas.

Array Signal Processing—J. H. Justice, N. L. Owsley, J. L. Yen, and A. C. Kak (Englewood Cliffs, NJ: Prentice-Hall, 1985, 433 pp.). *Reviewed by David G. Long.*

The field of array processing has grown rapidly in recent years due to the development of high speed digital computers. Historically, many different disciplines have been using array processing techniques almost independently. This book pulls together many of the different applications for array processing under one cover. It is designed as an introductory graduate level course in array processing. The described purpose of the book is to give a unified overview of such diverse applications of array signal processing as seismic exploration, sonar, radar, radio imaging, and tomographic imaging.

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The book consists of six chapters, each of which is written by a different author who is a specialist in the particular discipline. Chapter 1, which serves as an introduction, reviews basic concepts of wave propagation. The remainder of the chapters may be read more or less independently of each other.

Chapter 2 deals with seismic applications of array processing. Considering the breadth of the topic, the writer of this chapter has provided an excellent overview of the field of exploratory seismic processing and has included extensive derivations of the models and processing methods discussed. The author provides a brief historical background for each technique discussed. The bibliography for this chapter is prodigious with over 300 references.

Chapter 3 discusses passive sonar applications for array processing. Rather than providing a broad overview of sonar array processing similar to that given seismic processing in Chapter 2, the writer concentrates only on recent developments in passive sonar noise cancellation and interference. The writer of Chapter 3 does not adequately discuss signal modeling nor provide the motivation for various techniques as provided in other chapters of the book. There are a total of 118 references in this chapter.

Radar array processing is discussed in Chapter 4. The writer has restricted his discussion to linear arrays for solving the problem of angle-of-arrival estimation. The presentation describes basic signal and multipath models. Various methods of estimating the radar return spectrum are derived and related to the angle estimation problem. Adaptive antenna algorithms are also briefly discussed. Experimental results and computer simulations of some of the methods are presented. Seventy-two references are included in the bibliography of this chapter.

Chapter 5 is a review of the current state-of-the-art for image reconstruction of radio astronomy sources. After a discussion of electromagnetic wave fields of astronomical radio sources and of mutual coherence, the author describes two methods of image reconstruction: Fourier inversion and "CLEAN." He briefly dismisses the maximum-likelihood method. Some of the problems of each method are described and illustrated. The effects of antenna array configuration are also discussed. This chapter includes 83 references

Chapter 6 presents a sampling rather than a survey of tomographic imaging. This chapter presents an excellent background of the field. Signal models presented consider both diffracting and nondiffracting sources. The author describes some of the applications of tomographic imaging and presents the fundamental theorems for tomographic imaging. The remainder of the chapter consists of descriptions of various reconstruction algorithms including algebraic reconstruction, filtered-backprojection, and filtered-backpropagation algorithms. The chapter contains 105 references.

Although not designed to be an in-depth study of each subject, the book is more than adequate to serve as a text for a graduate course in array processing. Unfortunately, no homework problems are included in the text. The text is primarily theory oriented with little or no emphasis on hardware implementations of the array processing algorithms discussed. This book would make an excellent addition to the reference libraries of IEEE members.

Sprachverarbeitung und Sprachuebertragung (Speech Processing and Speech Transmission)—Klaus Fellbaum (Berlin, New York: Springer, 1984, IX + 274 pp.). *Reviewed by Hermann Ney.*

The stated objective of the book is to describe the state of the art in speech processing and transmission and to present the most funda-

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mental principles. A relatively large part of the book is allocated to the field of the sound and electroacoustic transducers. The book addresses mainly beginners and not the experts. No previous knowledge of the field is assumed, and the mathematics is kept to relatively simple forms, or if necessary as in the case of the wave equation, the mathematical formalism is explained using the physical problem under consideration. The book is based on lectures that were given by the author at the Technical University of Berlin and were intended primarily for students of electrical engineering.

The book consists of the following chapters:

Chapter 1 provides an introduction to the acoustic theory of sound, sound propagation and electroacoustic transducers. The sound equation is derived starting from basic principles. The typical applications of the wave equation are studied, such as plane (single frequency) waves, sound propagation in tubes, spherical waves and sound radiation. Then the principle of electroacoustic transducers is described, and several types of microphones (carbon, electrodynamic, -magnetic, -static) are considered in more detail.

Chapter 2 deals with the anatomy and physiology of the vocal tract, the production of speech and the classification of the different speech sounds. The author explains and defines the difference between phonetics and phonology and continues with the introduction and definitions of basic units in speech, such as phones, allophones, phonemes, syllables, demisyllables, morphes and morphemes. The tube model of speech production is shortly presented, and examples of several sounds spoken in isolation are given, both in terms of waveforms and spectra.

Chapter 3 is concerned with the hearing process. It describes the human ear and the theories of human hearing. The difference between the physical quantities describing the sound signal and the quantities describing the subjective auditory sensation is made clear. For example, critical bands and the effect of auditory masking are mentioned.

Chapter 4 is devoted to the question of how to define appropriate criteria of speech quality and how to measure speech intelligibility. As potential objective criteria, the "speech transmission index" and the "articulation index" are mentioned. Subjective criteria of speech

As potential objective criteria, the "speech transmission index" and the "articulation index" are mentioned. Subjective criteria of speech

Chapter 5 is the largest chapter and covers digital techniques for speech transmission. The author begins with what he calls signal form coding which includes pulse code modulation (PCM) and the sampling theorem, differential PCM (DPCM) and linear predictive coding (LPC), adaptive DPCM (ADPCM) and delta modulation (DM). The principle of the vocoder and its realizations are described along with the corresponding speech analysis techniques. The channel vocoder, LPC vocoder and various techniques of pitch period determination are described.

Chapter 6 deals with speaker and speech recognition. The difference between speaker verification and speaker identification is explained. Features well suited to the purpose of speaker recognition are discussed and some examples of speaker verification systems are described. The various tasks in speech recognition are defined: isolated word recognition, connected word recognition, continuous speech recognition, speaker dependent and speaker independent recognition. Isolated word recognition is described in more detail, along with nonlinear time alignment using dynamic programming. The features resulting from various speech analysis techniques are discussed under the recognition aspect. Then the author presents three examples of word recognition systems and shortly describes their principles and structures. Finally, the problems and techniques of continuous speech recognition are mentioned.

Chapter 7 provides a discussion of speech synthesis methods. A clear distinction between speech synthesis using prerecorded speech and text-to-speech synthesis is made. Formant and LPC synthesis techniques are described in more detail.

The significant strength of the book is that it represents a fairly complete sampling of topics relevant to any sort of work on speech processing, transmission and recognition. There is a clear emphasis on the fundamental principles and definitions on the one hand and on the techniques used for speech transmission on the other hand. The techniques of pattern recognition and statistical aspects are only touched upon in the book, which is obviously the author's intention. The book is well designed from a tutorial standpoint. Each chapter contains an appropriate list of references. Although the book may not necessarily be interesting for speech experts, such as ASSP readers, it reaches its objective, i.e., providing an introduction for those just starting in the field. While the book does a very good job of providing an introductory text, it may not be completely satisfactory for use in courses on statistical aspects in speech processing and on speech recognition. However, in view of the relatively small size of the book, it covers a surprisingly large field ranging from electroacoustic transducers to continuous speech recognition. The book can serve as a very readable introduction to speech processing, transmission and recognition.