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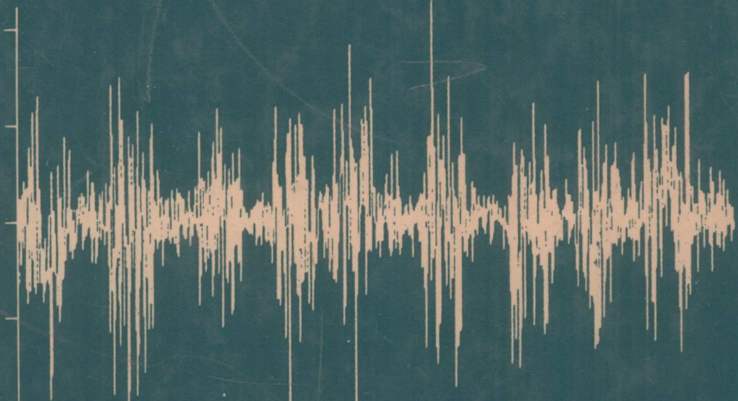

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STATISTICAL SIGNAL PROCESSING

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OTHER VOLUMES IN PREPARATION

To Christopher Andrew Wegman

Preface

Analog and digital signal processing are the cornerstones of much of modern technology, particularly of the computer revolution that is swelling up around us. The relation of the computer revolution to signal processing is a dual relationship. On the one hand, the wide availability of computers implies an ever greater capability to generate and transmit information in an ever more cluttered environment. This inevitably leads to noisier communications and a requirement to process signals which are at best stochastically masked by noise and which, in fact, may be themselves stochastic in character. On the other hand, the wide availability of computing power implies that sophisticated mathematical and statistical techniques may be brought to bear on the digital processing of signals rather than only processing by the relatively simple electronic circuits of the past. The development of mathematical and statistical tools for signal processing is inextricably bound up with the availability of computational power to implement these tools. This book and the workshop from which it arose are intended to span the intellectual range of statistical signal processing methodology from the somewhat esoteric realm of abstract stochastic process theory to the exciting, fast-paced world of VLSI computing architectures for implementing these algorithms.

The book is conceptually divided into six parts roughly ordered from abstract research to applications. The first section deals with Time Series Analysis and Stochastic Processes. This section is intended to lay the foundations of statistical inference about stochastic processes, the generic archetype of signals we consider later. Emphasis in this area is on the nonstandard (i.e., non-Gaussian) finite-dimensional distributional structures that characterize so many of the present signal processing environments.

The second section focuses on Signal Estimation and Detection. Signal detection particularly is an extremely challenging statistical problem. In the stochastic process setting it is several orders of magnitude more difficult than the iid cases usually encountered in standard discussions of statistical hypothesis testing. Again, in this area, our emphasis has been on moving beyond the usual Gaussian assumptions to distributional assumptions that more realistically model actual signal and noise characteristics.

The focus of the third section shifts to Data Analysis and Modeling. The availability of computing resources has at least two profound implications on the type of data which may be collected. Data may be and are frequently taken in much larger volume and are of a higher dimensional character. This is particularly true of data such as signal data which are generated, monitored and transmitted electronically. Moreover, the volume and dimensionality of this data allow a far more incisive inference about the fine-structure of the underlying mechanism. The point to be made is that dealing with 4,000,000 observations and dealing with 200 observations are fundamentally different chores even though standard theory may say that n can equal 200 or n can equal 4,000,000. The purpose of this section is to formulate approaches to this chore as well as to document empirically some of the distribution character of signals.

The detection of a signal is usually only the first step to the useful exploitation of information. Our next section focuses on Array Processing and Target Tracking. Array processing is essentially a synonym for antenna theory or spatial processing and is based on the idea that a spatially distributed set of sensors can be used to discover directional information about signal sources. Target tracking refers to the exploitation of array processing to locate and separate distinct signal sources as they move in time. This task is obviously of prime interest to the sonar-oriented Naval community.

Our fifth section focuses on Statistical Image Processing and, of course, specializes in stochastic processes (signals) with a two-dimensional domain. Digital imaging, in fact, video in general is a topic of tremendous technical interest. The interplay of computing resources and mathematical techniques is probably tested in this area more than any other type of signal processing commonly found. Emphasis here is on innovative mathematical and statistical approaches to image processing.

Our final section deals with Architecture for Signal Processing and is potentially one of the most fascinating displays of high technology presently on the scene. Advances in physical electronics are staggering with the now available very large scale integrated-circuit (VLSI) and the possibility of one-half micron devices looming on the horizon. The sheer density of circuits on such a chip preclude the manual design of every element and therefore imply chips must contain many repetitions of relatively simple processors. Perhaps this is the area where the interplay of mathematics and computing finds its most elegant expression.

This volume is the proceedings of a Workshop on Signal Processing in the Ocean Environment held at the US Naval Academy on 11-15 May 1982. All of the work represented in this volume is work carried out with support of the Office of Naval Research (ONR) in the area of Signal Processing. The scope of this work is enormous and the logistics associated with the workshop were complex. We would particularly like to thank Dr. Douglas J. DePriest, our associate in the ONR Statistics and Probability Program, for his superb handling of local arrangements and his exceptional efforts to insure a smooth-running workshop. Dr. Tom Sanders of the Mathematics Department of the US Naval Academy was a most gracious host and we deeply appreciate his efforts on our behalf.

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