Time Series and System Analysis with Applications by Sudhakar Madhavrao Pandit and Shien-Ming Wu

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Citation: The Journal of the Acoustical Society of America **75**, 1924 (1984); doi: 10.1121/1.390924
View online: https://doi.org/10.1121/1.390924
View Table of Contents: https://asa.scitation.org/toc/jas/75/6
Published by the Acoustical Society of America

ability of the sea surface. Nevertheless two of the authors make the attempt to profit from these models by using their predictions as input data for a more adapted array processor design.

In summary: the book is an important collection of advanced research papers on sea-bed acoustics.

Almost all authors made a good and well-balanced use of illustrative material to clarify their theoretical or experimental results, supplying comprehensive reference lists. Since there are no tutorial papers in this volume it may be of limited interest for those with no *a priori* knowledge of the subject matter. The few minor objections made above are merely due to the fact that this book is a collection of original papers which are presented without any editing. Nevertheless the homogeneity of most chapters is exceptional due to the high quality of the submitted contributions, reflecting the state-of-the-art as of mid 1980. Accordingly the minor criticisms do not minimize the overall good impression of this book, which is strongly recommended to marine geologists, underwater acousticians, and sonar system designers.

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MSA—Mechanical Signature Analysis

Simon Braun, Ed.

ASME Part G-00236, ASME, New York, 1983.
88 pp. Price $34.00 (non-members); $17.00 (members).

The term "signature" denotes signal patterns which define the state or propagation of systems from which they are obtained. MSA concerns itself with those primarily involving vibration. However, one may also obtain other variables. The prime intent of these variables is to obtain information from the data concerning the behavior of mechanical systems. MSA occurs in various inter-related domains. In its function as a diagnostic tool, vibration analysis is one of its prime practices. This nondestructive measuring technique has had a succession of garnering meaningful data. At present, it is applied in quality control as well as monitoring schemes. By following small changes in the long period of time in monitoring, these factors can be tracked via the high-frequency vibration signals. An important MSA application occurs in the field of structural testing where modal parameters are identified via response to excitations. The field of noise abatement also involves some aspects of MSA techniques. The common aspect in all of these practices is to procure and remove information founded on signal patterns. The basic instrumentation employed in allied fields requires similar implementation in the quest for useful data. Recently, some experimental work has been conducted in the allied field of acoustics.

This little volume consists of ten papers.

The initial paper discusses the design of a high level diagnostic system. This relates to the employment of a few sensors, remote from a number of vibration generating mechanisms. Employing multiple sensors and advanced signal processing, the authors use this diagnostic system in detecting the combustion and gear mesh excitations in a diesel engine.

The second paper reports on the early detection and diagnosis of machine faults on the "TransAlaska Pipeline." The authors use power spectra and the corresponding cepstrum. By using the latter, they were able to detect early outer race faults of a ball bearing approximately eight months prior to shutdown for repair. This technique has been applied to other major equipment on the pipe line, i.e., gas turbines, reaction turbines, and pumps.

The third paper explains the detection of a misaligned disk coupling using spectrum analysis. This is based upon the analysis of structural vibrations brought about by misalignment.

The next paper introduces the use of signal analysis and identification methods for correction of mass imbalance on a rotating machine. This contrivance employs conditioned signals, spectra and primarily the multiple coherence function. This is applied to an eight cylinder combustion engine mounted on a test stand.

The fifth paper, being mathematical in nature, presents a method for recognizing structural nonlinearities in steady-state harmonic testing from test data. The authors define the level of nonlinearity by a single parameter, called the J factor. An example and application of the J factor are furnished in this paper.

The next paper explains the reduction bias error in transfer functions using FFT based analyzers. The author shows that the accuracy of the transfer function estimates from an FFT based spectrum analyzer depends on the product of frequency f_n, damping factor η, divided by the frequency resolution Δf. Additional hints are furnished concerning shaker excitation on lightly damped structures, frequency resolution (zoom-band selectable analysis), and methods of reducing the bias error on transfer function estimates.

The seventh paper presents a technique for predicting the multiple input force time histories acting on a machinery component through the use of vibration measurements and a stored matrix of mechanical frequency response functions. This technique involves a least squares pseudoinverse (PDI) of the transfer functions, using single decomposition (SD) in the frequency domain. SD conditions the PDI against possible singularities due to uncertainties in the data. This inverse filter can separate multiple input force signals even in the case of contamination from outside sources on the vibration signal.

The eighth paper compares the traditional Fourier transform (DFT) with the recently developed Maximum Entropy Spectral Method (MESA) as applied to vibration analysis. Simulated and actual vibration data were analyzed to yield estimates of the power spectral density by MESA and DFT techniques. MESA estimates furnish smoother curves without the "leakage" associated with DFT plus a narrower bandwidth for the resonance peak. However the MESA requires careful determiantion of the predicted error filter used in the analysis. The reviewer feels that MESA has great potential in power spectral determination and analysis.

The ninth paper compares the Fourier transform and three parametric methods as techniques in the analysis of data acquired from a vibrating structure. The parametric methods include the Prony's series, Recursive Least Squares (RLS) and Instrumental Variable Analysis (IV). For low signal to noise ratio, the RLS and Prony methods deteriorate. The IV method performs very well when there is noise in the data. These are viable alternatives to the Fourier transform methods. However, it is difficult to judge which method furnishes the best results.

The final paper discusses the computerized system that was selected and the software developed for random vibration and acoustic analysis. The authors present short statements of the mathematical procedures employed with applications to the study of the measured vibration in flight.

In summary, this was a good symposium. The state-of-the-art of digital signal processing is steadily advancing. This is not the final word. Newer and better techniques are always appearing on the horizon.

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Time Series and System Analysis with Applications

Sudhakar Madhavrao Pandit and Shien-Ming Wu

John Wiley and Sons, New York, 1983.
xviii + 586 pp. Price $39.95.

This text is the first systematic booklength treatment of time-series modeling via the Autoregressive Moving Average (ARMA) approach. The book is self-contained, allowing the use of it as a text or for self-study. It builds the reader's intuition by thoroughly discussing first- and second-order examples and models prior to generalizing. Thereafter it treats the most general case needed for any stable system, the ARMA(n, $n-1$) model, with n poles and $n - 1$ zeros to be fitted. A model adequacy test, using the F distribution on the residual sum of squares, checks whether the last increase in model order, n, improved the time series fit. Sample time series data from various applications are listed in an appendix, including such diverse matters as mechanical vibration and sunspot data. ARMA model fits of various orders are given for selected illustrative examples. Of special interest to *Journal* readers, Chap. 7 discusses the random vibration of a linear mechanical second-order system. Problems at the end of the chapters allow the reader to apply the theory. Last, but by no means least, there is a FORTRAN 77 program listing in an appendix, both for doing "univariate" (single time series) ARMA modeling, with optional deterministic trend estimation, as well as for "multivariate" (multiple time series) extended ARMA (EARMA).

After giving a helpful overview of the book in the first chapter, the authors place ARMA models in the context of least square estimates in multiple regression, through the "Wold's decomposition" (into uncorrelated random variables) concept. Stability and invertibility are discussed in Chap. 3, and are related to the properties of the time series autocorrelation and power spectrum ("autospectrum"). Chapter 4 motivates the use of an ARMA $(n, n - 1)$ approach, and discusses modeling procedures, model order adequacy checks, and illustrative examples of the approach. For detailed justification of the approximation adequacy criterion the reader is referred to Pandit's 1973 Ph.D. thesis. Time series prediction (forecasting) is discussed next. Then, Chap. 6 discusses how the previous chapters' discrete-time results relate to time-sampled continuous-time systems. As mentioned, Chap. 7 discusses the linear mechanical oscillator, and these results are related to other applications in the next chapter, discussing prediction as exponential smoothing. The modeling and the detection of a nonstationarity in a time series is discussed in Chap. 10, after Chap. 9 has set the stage by examining examples of stochastic trends and seasonality. Pandit and Wu proudly show how the ARMA model enables one to find nonstationarity and trends automatically, without having to use possibly misleading, *ad hoc*, trend-removing preprocessing. The last chapter (11) shows how to generalize from single to multiple time series for the case where the input noise is independent of output noise (estimation error), and that these estimation errors are mutually independent. A selected list of references and an application bibliography follow.

This book deserves reading by all time series modelers and analysts, since it provides a unified systematic procedure for fitting the widely useful ARMA models, even including a computer program. It gives a more rigorous procedure for determining the model order than do previous (if unreferenced) treatments in the engineering literature. One only wishes that the authors had interacted also with the spectral estimation ARMA modeling work in speech and various electrical engineering areas. For example, the excellent book of reprints, *Modern Spectrum Analysis,* edited by Donald G. Childers (IEEE, New York, 1978) should have been cited, to make up for the lack of references to the relevant papers therein. And, meanwhile, a Special Issue on Spectrum Estimation has come out in the September 1982 Proceedings of the IEEE, edited by Simon Haykin and James A. Cadzow, which brings the EE aspect up to date. Still, this does not really detract from the great value of Pandit and Wu's book, for which all signal processors should be grateful; it does suggest the need for closer interdisciplinary interaction of all random signal analysts.

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