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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Spline estimates of probability density functions were considered and the asymptotic bias and variance of these estimates were determined. Bispectral estimates were employed as a means of getting information about aspects of the nonlinear transfer of energy in turbulence.

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The behavior of k-dimensional kernel density (probability) estimates was examined.

The asymptotic behavior of partial sums of dependent random variables was also examined.

The relationship between long-range dependence and non-Gaussian structure of the limiting distributions was determined in some cases.

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RANDOM TIME PROCESSES

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Introduction. The duration of the contract N00014-75-C-0428 was from January 1, 1975 to march 31, 1981. The principal investigator was Murray Rosenblatt of the Department of Mathematics at U.C.S.D. The following list contains the names of other people who were supported at some time.

Richard Bradley
Richard Davis
Larry Goldstein
Dr. Kenneth Helland
Dr. Keh-Shin Lii
Y. P. Mack
Dr. John Rice
Daniel Sorenson
Stewart Strait

List of doctoral theses. The following doctoral theses were completed by students working with the principal investigator. These students were supported in part by funds from the ONR contract.

Keh-Shin Lii "On a global measure of the deviation of a spline estimate of a density function" 1975

Yue-Pok Mack "k-nearest neighbor estimation" 1978

Richard Bradley, Jr. "Measure of dependence on stationary sequences of random variables" 1978

Richard Davis "Extremes of stationary processes" 1979

Stewart Strait "A quadratic measure of deviation of spectral estimates" 1979

List of research papers published. Below a list is given of papers supported in part by the contract. The papers with no attribution are authored by M. Rosenblatt.

1. (with Keh-shin Lii) "Asymptotic behavior of a spline estimate of a density function" Comp. and Maths. with Appl. 1, 223-235, 1975.

2. "Multiply schemes and shuffling" Math. of Comput. 29, 929-934, 1975.

3. "The local behavior of the derivative of a cubic spline interpolator" J. Approx. Th. 15, 382-387, 1975.

4. "Asymptotics and representation of cubic splines" J. Approx. Th., 17, 332-343, 1976.

5. (with Keh-Shin Lii and C. Van Atta) "Bispectral measurements In turbulence" J. Fluid Mech. 77, 45-62, 1976

6. "On the maximal deviation of k-dimensional density estimates" Ann. Prob., 4, 1009-1015, 1976

7. "Fractional integrals of stationary processes and the central limit theorem" J. Appl. Prob., 13, 723-732, 1976

8. (with P.A. W. Lewis, L. H. Liu and D. W. Robinson) "Empirical sampling study of a goodness of fit statistic for density function estimation" Multivariate Analysis IV, 159-174, 1977

9. (with John Rice) "Estimation of the log survivor function and hazard function" Sankhya, 38 Series A, Pt. 1, 60-78, 1976

10. (with K. N. Helland and K. S. Lii) "Bispectra of atmospheric and wind tunnel turbulence" Appl. of Statistics, 223-248, 1977

11. "Energy transfer for the Burgers equation" Phys. Fluids 21, 1694-1697, 1978

12. (with K.N. Helland) "Spectral variance estimation and the analysis of turbulence", Phys. Fluids, 22, 819-823, 1979

13. (with K.N. Helland and K.S. Lii) "Bispectra and energy transfer in grid-generated turbulence" Develop. in Statist. Vol. 2, 123-155, 1979

14. "Some remarks on a mixing condition" Ann. Prob. 7, 170-172, 1979

15. (with Y.P. Mack) "Multivariate k-nearest neighbor density estimates" J. Multiv. Anal., 9, 1-15, 1979

16. Richard A. Davis "Maxima and minima of stationary sequences" Ann. Prob., 7, 453-460, 1979

17. Richard C. Bradley "A remark on the central limit theorem for dependent random variables" J. Appl. Prob., 17, 94-101, 1980

18. Richard C. Bradley "On the strong mixing and weak Bernoulli conditions" Zeit. f. Warschein. 51, 49-54, 1980

19. Richard C. Bradley "A note on a mixing condition Ann. Prob., 8, 636-638, 1980

20. Y. P. Mack "Asymptotic normality of multivariate k-nn density estimates" Sankhya, 42, Series A, 1980

21. "Some limit theorems for partial sums of stationary sequences" Multivariate Analysis V 239-248, 1980

22. "Some limit theorems for partial sums of quadratic forms in stationary Gaussian variables, Zeit. f. Warschein. 49, 125-132, 1979

23. "Linear processes and bispectra" J. Appl. Prob. 17, 265-270, 1980

Discussion of the research

In the discussion of research, papers will be referred to by numbers as they are enumerated in the list of research papers published.

The paper [1] considered spline estimates of probability density functions as suggested by Boneva, Kendall and Stepanov and determined the asymptotic bias and variance of these estimates. They were also shown to be asymptotically normal under appropriate conditions. The results of [1] were based in part on [3] where the error terms in cubic spline interpolation were precisely estimated asymptotically. In [4], the effects of the boundary in the case of a cubic free spline interpolator are shown to be the major contribution to the integrated square error. The results of [2] suggest the type of improvement shuffling makes in the generation of pseudo-random numbers.

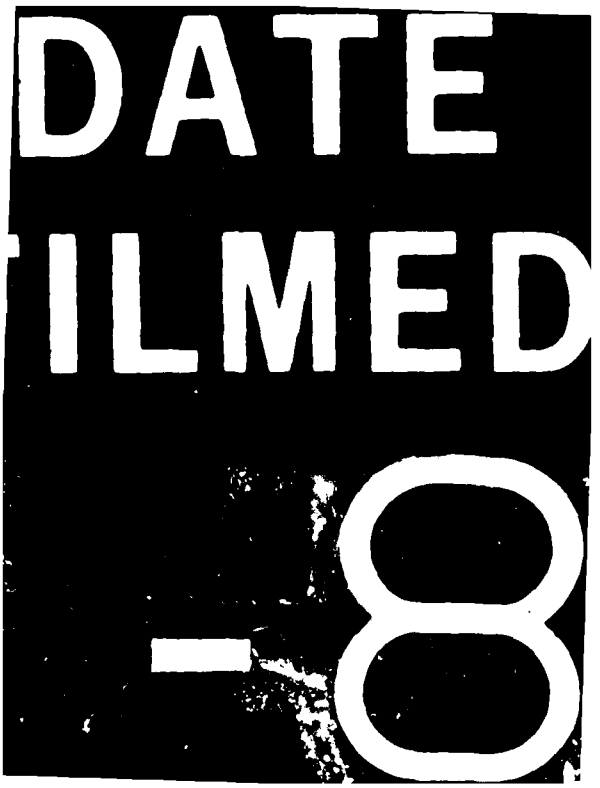
Bispectral estimates are employed in the multiple author paper [5] as a means of getting information about aspects of the nonlinear transfer of energy in turbulence. It is applied in the analysis of atmospheric data. These ideas are employed in a more extensive analysis of atmospheric and wind tunnel turbulence in [10] and [13]. A discussion of energy transfer for the model Burgers equation is to be found in [11].

The behavior of k-dimensional kernel density (probability) estimates is examined in [6]. An empirical Monte Carlo study of the behavior of a quadratic goodness of fit statistic for a density function estimate is carried out in [8]. The asymptotic behavior of multivariate k-nearest neighbor density estimates is determined in [15]. Related ideas are used to compare and evaluate the behavior of a number of estimates of the log survivor function and hazard function when the data is dependent [9]. Such questions are of interest in the study of reliability.

The asymptotic behavior of partial sums of dependent random variables is examined in a number of papers. The dependent random variables are assumed to be stationary. In [7] conditions are specified under which one still gets asymptotic normality though the limiting normal process may not be the classical Brownian motion but rather a fractional Brownian motion. Related questions are taken up in [14] and [21]. In [22] cases are taken up in which there is sufficient long-range dependence and non-Gaussian structure so that the limiting distribution of partial sums is non-Gaussian and even nonstable. The normalization in these cases also turns out to be quite different from the standard normalization. Related questions of scale renormalization have been brought up in statistical physics and the study of turbulence.

In [16] the joint asymptotic distribution of maxima and minima of stationary sequences are determined under rather weak mixing conditions. In paper [17], [18], and [19] a number of mixing conditions for stationary sequences are examined. Some remarks are also made about the boundary of the domain within which the central limit theorem (asymptotic normality) is still valid for partial sums of dependent sequences.

Paper [23] considers linear non-Gaussian schemes and the problem of parameter estimation for such schemes. The sense in which Gaussian linear schemes are atypical is remarked on.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