

THE ANNALS of STATISTICS

ISSN (0090-5364)

AN OFFICIAL JOURNAL OF THE
INSTITUTE OF MATHEMATICAL STATISTICS

The 1987 Wald Memorial Lectures

A generalization of spectral analysis with application to ranked data PERSI DIACONIS 949

Articles

Asymptotic distributions of minimum norm quadratic estimators of the covariance function of a Gaussian random field	MICHAEL STEIN	980
Honest confidence regions for nonparametric regression	KER-CHAU LI	1001
Regression analysis under link violation	KER-CHAU LI AND NAIHUA DUAN	1009
Adaptive nonparametric peak estimation	HANS-GEORG MÜLLER	1053
On the relationship between stability of extreme order statistics and convergence of the maximum likelihood kernel density estimate MICHEL BRONIATOWSKI, PAUL DEHEUVELS AND LUC DEVROYE		1070
Very weak expansions for sequentially designed experiments: Linear models MICHAEL WOODROOFE		1087
Edgeworth expansions for linear rank statistics	WALTER SCHNELLER	1103
Asymptotic expansions of some mixtures of the multivariate normal distribution and their error bounds	YASUNORI FUJIKOSHI AND RYOICHI SHIMIZU	1124
Right censoring and martingale methods for failure time data	MARTIN JACOBSEN	1133
Uniform consistency of the kernel conditional Kaplan–Meier estimate DOROTA M. DABROWSKA		1157
On the bootstrap of the sample mean in the infinite variance case	KEITH KNIGHT	1168
A general theory for jackknife variance estimation	JUN SHAO AND C. F. J. WU	1176
Bootstrapping the maximum likelihood estimator in high-dimensional log-linear models	WILHELM SAUERMAN	1198
The jackknife and the bootstrap for general stationary observations	HANS R. KÜNSCH	1217
Robust nonparametric regression estimation for dependent observations GRACIELA BOENTE AND RICARDO FRAIMAN		1242
Model selection under nonstationarity: Autoregressive models and stochastic linear regression models	B. M. PÖTSCHER	1257
A fixed point characterization for bias of autoregressive estimators ROBERT A. STINE AND PAUL SHAMAN		1275
Generalized chi-square goodness-of-fit tests for location-scale models when the number of classes tends to infinity	F. C. DROST	1285
Asymptotic analysis of minimax strategies in survey sampling	HORST STENGER	1301
Minimaxity of randomized optimal designs	PETER M. HOOPER	1315
Optimal-partitioning inequalities in classification and multi-hypotheses testing	THEODORE P. HILL AND Y. L. TONG	1325
An asymptotic lower bound for the local minimax regret in sequential point estimation	MOHAMED TAHIR	1335
Inadmissibility of the empirical distribution function in continuous invariant problems	QIQING YU	1347
A general theorem on decision theory for nonnegative functionals: With applications	ANIRBAN DASGUPTA	1360
The Stein paradox in the sense of the Pitman measure of closeness PRANAB KUMAR SEN, TATSUYA KUBOKAWA AND A. K. MD. EHSANES SALEH		1375
A robust Bayesian interpretation of likelihood regions	LARRY ALAN WASSERMAN	1387
Locally coherent rates of exchange	THOMAS E. ARMSTRONG AND WILLIAM D. SUDDERTH	1394
A geometric interpretation of Darroch and Ratcliff's generalized iterative scaling IMRE CSISZÁR		1409

Corrections

Complete classes for sequential tests of hypotheses L. D. BROWN, ARTHUR COHEN AND W. E. STRAWDERMAN		1414
Empirical processes associated with V -statistics and a class of estimators under random censoring	MICHAEL G. AKRITAS	1417

Vol. 17, No. 3—September 1989



INSTITUTE OF MATHEMATICAL STATISTICS

(Organized September 12, 1935)

The purpose of the Institute is to foster the development and dissemination of the theory and applications of statistics and probability.

OFFICERS AND EDITORS

- President:** Shanti S. Gupta, Department of Statistics, Purdue University, West Lafayette, Indiana 47907
- President-Elect:** David O. Siegmund, Department of Statistics, Sequoia Hall, Stanford University, Stanford, California 94305
- Past President:** Ram Gnanadesikan, Morris Research and Engineering Center, Bell Communications Research, 435 South Street, Morristown, New Jersey 07960-1961
- Executive Secretary:** Peter Purdue, Department of Operations Research, Code 55, Naval Postgraduate School, Monterey, California 93943
- Treasurer:** Jessica Utts, Division of Statistics, University of California, Davis. *Please send correspondence to:* IMS Business Office, 3401 Investment Boulevard #7, Hayward, California 94545
- Program Secretary:** Lynne Billard, Department of Statistics, University of Georgia, Athens, Georgia 30602
- Editor, *The Annals of Statistics*:** Arthur Cohen, Department of Statistics, Busch Campus, Rutgers University, New Brunswick, New Jersey 08903
- Editor, *The Annals of Probability*:** Peter Ney, Department of Mathematics, Van Vleck Hall, University of Wisconsin, 480 Lincoln Drive, Madison, Wisconsin 53706
- Executive Editor, *Statistical Science*:** Carl N. Morris, Statistical Sciences Center, RLM 8.100, University of Texas, Austin, Texas 78712
- Editor, *The IMS Bulletin*:** George P. H. Styan, Department of Mathematics and Statistics, Burnside Hall, McGill University, 805 Sherbrooke Street West, Montreal PQ, Canada H3A 2K6
- Editor, *The IMS Lecture Notes—Monograph Series*:** Robert J. Serfling, Department of Mathematical Sciences, Johns Hopkins University, Baltimore, Maryland 21218
- Managing Editor:** Paul Shaman, Department of Statistics, University of Pennsylvania, Philadelphia, Pennsylvania 19104-6302

Journals. The scientific journals of the Institute are *The Annals of Statistics*, *The Annals of Probability* and *Statistical Science*. The news organ of the Institute is *The Institute of Mathematical Statistics Bulletin*.

Individual, Institutional and Corporate Memberships. All *individual members* receive *The IMS Bulletin* for a basic annual dues rate of \$30. Each member must elect to receive at least one scientific journal for an additional amount, as follows: *Statistical Science* (\$5), one *Annals* (\$15) or both *Annals* (\$25). Dues allocations to each journal are set by Council resolution. Of the total dues paid, \$12 is allocated to *The IMS Bulletin* and the remaining amount is allocated equally among the scientific journal(s) received. Memberships are available at a reduced rate (40% of regular rates) for full-time students, permanent residents of developing countries and retired members. Retired members may also elect to receive the *Bulletin* only for \$12. *Institutional memberships* are available to nonprofit organizations at \$270 per year and *corporate memberships* are available to other organizations at \$585 per year. Institutional and corporate memberships include two multiple-readership copies of all IMS journals in addition to other benefits specified for each category (details available from the IMS Business Office).

Individual and General Subscriptions. Subscriptions are available on a calendar-year basis. *Individual subscriptions* are for the personal use of the subscriber and must be in the name of, paid directly by and mailed to an individual. Individual subscriptions for 1989 are available to both *Annals* and *Statistical Science* (\$96), one *Annals* and *Statistical Science* (\$60), both *Annals* (\$72), one *Annals* (\$45), *Statistical Science* (\$30) and *The IMS Bulletin* (\$20). *General subscriptions* are for libraries, institutions and any multiple-readership use. For 1989, all general subscriptions to one or both *Annals* automatically include one subscription to *Statistical Science*. General subscriptions for 1989 are available to both *Annals* and *Statistical Science* (\$180), one *Annals* and *Statistical Science* (\$105), *Statistical Science* only (\$45) and *The IMS Bulletin* (\$30). Air mail rates for overseas delivery of general subscriptions are \$50 per title.

Permissions policy. Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by the Institute of Mathematical Statistics, provided that the base fee of \$5.00 per copy, plus \$.00 per page is paid directly to the Copyright Clearance Center, 27 Congress Street, Salem, Massachusetts 01970. For those organizations that have been granted a photocopy license by CCC, a separate system of payment has been arranged. The fee code for users of the Transactional Reporting Service is: 0090-5364/89 \$5.00 + .00.

Correspondence. Mail to IMS should be sent to the IMS Business Office (membership, subscriptions, claims, copyright permissions, advertising, back issues), the Editor of the appropriate journal (submissions, editorial content) or the Managing Editor (production).

The Annals of Statistics (ISSN 0090-5364), Volume 17, Number 3, September, 1989. Published in March, June, September and December by the Institute of Mathematical Statistics, 3401 Investment Boulevard #7, Hayward, California 94545. Second-class postage paid at Hayward, California and at additional mailing offices. **Postmaster:** Send address changes to *The Annals of Statistics*, Institute of Mathematical Statistics, 3401 Investment Boulevard #7, Hayward, California 94545.

EDITORIAL STAFF

EDITOR

ARTHUR COHEN

ASSOCIATE EDITORS

JAMES O. BERGER
PETER J. BICKEL
LAWRENCE D. BROWN
ANDREAS BUJA
CHING-SHUI CHENG
DENNIS D. COX
LINDA J. DAVIS
MORRIS L. EATON
DAVID F. FINDLEY
RICHARD D. GILL

FRIEDRICH GÖTZE
PETER HALL
IAIN M. JOHNSTONE
ESTATE V. KHMALADZE
HANS R. KÜNSCH
STEVEN LALLEY
KER-CHAU LI
BRUCE G. LINDSAY
WEI-YIN LOH
J. S. MARRON

IAN W. MCKEAGUE
ROBB J. MUIRHEAD
DAVID RUPPERT
MARK SCHERVISH
DAVID W. SCOTT
DAVID O. SIEGMUND
TERRY SPEED
CHING-ZONG WEI
MICHAEL WOODROOFE
JAMES V. ZIDEK

EDITORIAL ASSISTANT
APRIL ALLRIDGE

MANAGING EDITOR
PAUL SHAMAN

EDITORIAL ASSISTANT
TANYA WINDER

PAST EDITORS

THE ANNALS OF MATHEMATICAL STATISTICS

H. C. CARVER, 1930–1938
S. S. WILKS, 1938–1949
T. W. ANDERSON, 1950–1952
E. L. LEHMANN, 1953–1955
T. E. HARRIS, 1955–1958

WILLIAM KRUSKAL, 1958–1961
J. L. HODGES, JR., 1961–1964
D. L. BURKHOLDER, 1964–1967
Z. W. BIRNBAUM, 1967–1970
INGRAM OLKIN, 1970–1972

THE ANNALS OF STATISTICS

INGRAM OLKIN, 1972–1973
I. R. SAVAGE, 1974–1976
RUPERT G. MILLER, JR., 1977–1979
DAVID V. HINKLEY, 1980–1982
MICHAEL D. PERLMAN, 1983–1985
WILLEM R. VAN ZWET, 1986–1988

THE ANNALS OF PROBABILITY

RONALD PYKE, 1972–1975
PATRICK BILLINGSLEY, 1976–1978
R. M. DUDLEY, 1979–1981
HARRY KESTEN, 1982–1984
THOMAS M. LIGGETT, 1985–1987

EDITORIAL POLICY

The main purpose of *The Annals of Statistics* and *The Annals of Probability* is to publish significant contributions to the theory of statistics and probability and their applications. The emphasis is on importance and interest; formal novelty and mathematical correctness alone are not sufficient for publication. Especially appropriate are authoritative expository papers and surveys of areas in vigorous development. Because statistics is an evolving discipline, the Editors of *The Annals of Statistics* take a broad view of its domain and welcome papers in interface areas. Contributors to *The Annals of Statistics* should review the editorial in the January 1980 issue. All papers are refereed.

ADDITIONAL GUIDELINES FOR PREPARING PAPERS FOR THE ANNALS OF STATISTICS

1. The introduction and/or abstract should contain a statement pertaining to the statistical importance of the paper. Sometimes this is clear when reference is made to previous work. Statistical importance, not mathematical complexity for its own sake, is the prime criterion for publication.
2. The introduction should be thorough and contain clear yet nontechnical descriptions of the important results. Furthermore, the introduction should give a clear indication of where in the paper the main results and conclusions are to be found.
3. In papers where the formulation is general and mathematically abstract, when appropriate, the author should provide a short development of a special case, an example, or an illustration of the results. If possible, the special case or example should be in the introduction or shortly thereafter.
4. The manuscript should be proofread thoroughly before being submitted. Manuscripts with many typographical errors will cause unnecessary delays and may require resubmission.

IMS CORPORATE MEMBERS

THE AEROSPACE CORPORATION
Los Angeles, California

AT & T BELL LABORATORIES
Murray Hill, New Jersey

BELL COMMUNICATIONS RESEARCH
Morristown, New Jersey

GENERAL MOTORS CORPORATION
Research Laboratories
Warren, Michigan

INTERNATIONAL BUSINESS MACHINES CORP
Thomas J. Watson Research Center
Yorktown Heights, New York

SPRINGER-VERLAG NEW YORK INCORPORATED
New York, New York

IMS INSTITUTIONAL MEMBERS

ACADEMIA SINICA
Inst of Statistical Science
Taipei, Taiwan

AMERICAN UNIVERSITY
Dept of Mathematics and Statistics
Washington, DC

ARIZONA STATE UNIVERSITY
Dept of Mathematics
Tempe, Arizona

AUSTRALIAN NATIONAL UNIVERSITY
Canberra, ACT, Australia

BOWLING GREEN STATE UNIVERSITY
Dept of Mathematics and Statistics
Bowling Green, Ohio

CALIFORNIA STATE UNIVERSITY
AT FULLERTON
Dept of Mathematics
Fullerton, California

CASE WESTERN RESERVE UNIVERSITY
Dept of Mathematics and Statistics
Cleveland, Ohio

CENTRE INTERNATIONAL DE
RECONTRE MATH
Marseille, France

CORNELL UNIVERSITY
Dept of Mathematics
Ithaca, New York

FLORIDA STATE UNIVERSITY
Dept of Statistics
Tallahassee, Florida

HARVARD UNIVERSITY
Dept of Biostatistics
Boston, Massachusetts

HARVARD UNIVERSITY
Dept of Statistics
Cambridge, Massachusetts

INDIANA UNIVERSITY
Dept of Mathematics
Bloomington, Indiana

INSTITUTO MEXICANO DEL PETROLEO
Mexico, DF, Mexico

IOWA STATE UNIVERSITY
Dept of Stat and Statistical Lab
Ames, Iowa

JOHNS HOPKINS UNIVERSITY
Dept of Biostatistics
Baltimore, Maryland

KANSAS STATE UNIVERSITY
Dept of Statistics
Manhattan, Kansas

MARA INSTITUTE OF TECHNOLOGY
Selangor, Malaysia

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Dept of Mathematics
Cambridge, Massachusetts

MIAMI UNIVERSITY LIBRARY
Oxford, Ohio

MICHIGAN STATE UNIVERSITY
Dept of Statistics and Probability
East Lansing, Michigan

NATIONAL SECURITY AGENCY
Fort George G. Meade, Maryland

NEW MEXICO STATE UNIVERSITY
Dept of Mathematical Sciences
Las Cruces, New Mexico

NORTH CAROLINA STATE UNIVERSITY
Dept of Statistics
Raleigh, North Carolina

NORTHERN ILLINOIS UNIVERSITY
Dept of Mathematical Sciences
DeKalb, Illinois

OHIO STATE UNIVERSITY
Dept of Statistics
Columbus, Ohio

OREGON STATE UNIVERSITY
Dept of Statistics
Corvallis, Oregon

PENNSYLVANIA STATE UNIVERSITY
Dept of Statistics
University Park, Pennsylvania

PRINCETON UNIVERSITY LIBRARY
Princeton, New Jersey

PURDUE UNIVERSITY LIBRARY
West Lafayette, Indiana

QUEEN'S UNIVERSITY
Dept of Mathematics and Statistics
Kingston, Ontario, Canada

RICE UNIVERSITY LIBRARY
Houston, Texas

THE ROCKEFELLER UNIVERSITY LIBRARY
New York, New York

SIMON FRASER UNIVERSITY
Dept of Mathematics and Statistics
Burnaby, British Columbia, Canada

SOUTHERN ILLINOIS UNIVERSITY
Dept of Mathematics and Statistics
Edwardsville, Illinois

SOUTHERN METHODIST UNIVERSITY
Dept of Statistics
Dallas, Texas

STANFORD UNIVERSITY
Dept of Statistics
Stanford, California

TEMPLE UNIVERSITY
Dept of Mathematics
Philadelphia, Pennsylvania

TEXAS TECH UNIVERSITY
Dept of Mathematics
Lubbock, Texas

UNIVERSITY OF ALBERTA
Dept of Statistics
and Applied Probability
Edmonton, Alberta, Canada

UNIVERSITY OF ARIZONA
Dept of Mathematics
Tucson, Arizona

UNIVERSITY OF BRITISH COLUMBIA
Dept of Statistics
Vancouver, British Columbia, Canada

UNIVERSITY OF CALGARY
Dept of Mathematics and Statistics
Calgary, Alberta, Canada

UNIVERSITY OF CALIFORNIA
Dept of Statistics
Berkeley, California

UNIVERSITY OF CALIFORNIA
Div of Statistics
Davis, California

UNIVERSITY OF FLORIDA
Dept of Statistics
Gainesville, Florida

UNIVERSITY OF GEORGIA
Dept of Statistics
Athens, Georgia

UNIVERSITY OF ILLINOIS
Dept of Statistics
Champaign, Illinois

UNIVERSITY OF ILLINOIS AT CHICAGO
Dept of Math, Stat, and Comp Sci
Chicago, Illinois

UNIVERSITY OF IOWA
Dept of Statistics and Acturial Sci
Iowa City, Iowa

UNIVERSITY OF MARYLAND
Dept of Mathematics
College Park, Maryland

UNIVERSITY OF MASSACHUSETTS
Dept of Mathematics and Statistics
Amherst, Massachusetts

UNIVERSITY OF MICHIGAN
Dept of Statistics
Ann Arbor, Michigan

UNIVERSITY OF MINNESOTA
School of Statistics
Minneapolis, Minnesota

UNIVERSITY OF MISSOURI
Dept of Statistics
Columbia, Missouri

UNIVERSITY OF MONTREAL
Dept of Mathematics
Montreal, Quebec, Canada

UNIVERSITY OF NEBRASKA
Dept of Mathematics and Statistics
Lincoln, Nebraska

UNIVERSITY OF NEW MEXICO
Dept of Mathematics and Statistics
Albuquerque, New Mexico

UNIVERSITY OF NORTH CAROLINA
Dept of Statistics
Chapel Hill, North Carolina

UNIVERSITY OF OREGON
Dept of Mathematics
Eugene, Oregon

UNIVERSITY OF OTTAWA
Dept of Mathematics
Ottawa, Ontario, Canada

UNIVERSITY OF SOUTH CAROLINA
Dept of Statistics
Columbia, South Carolina

UNIVERSITY OF STOCKHOLM
Inst of Actuarial Math and Math Stat
Stockholm, Sweden

UNIVERSITY OF TEXAS AT AUSTIN
Dept of Mathematics
Austin, Texas

UNIVERSITY OF TEXAS AT SAN ANTONIO
Div of Math, Comp Sci, and Systems Design
San Antonio, Texas

UNIVERSITY OF VICTORIA
Dept of Mathematics
Victoria, British Columbia, Canada

UNIVERSITY OF VIRGINIA
Dept of Mathematics
Charlottesville, Virginia

UNIVERSITY OF WASHINGTON
Dept of Statistics
Seattle, Washington

UNIVERSITY OF WATERLOO
Dept of Statistics and Actuarial Sci
Waterloo, Ontario, Canada

VIRGINIA COMMONWEALTH UNIVERSITY
Dept of Mathematical Sciences
Richmond, Virginia

**VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY**
Dept of Statistics
Blacksburg, Virginia

WAYNE STATE UNIVERSITY
Dept of Mathematics
Detroit, Michigan

YORK UNIVERSITY
Dept of Mathematics
Downsview, Ontario, Canada

THE ANNALS OF STATISTICS

INSTRUCTIONS FOR AUTHORS

Submission of Papers. Papers to be submitted for publication should be sent to the Editor of *The Annals of Statistics*. (For current address, see the latest issue of the *Annals*.) **Four copies** should be submitted on paper that will take ink corrections. The manuscript will *not* normally be returned to the author; when expressly requested by the author, one copy of the manuscript will be returned. All manuscripts should be accompanied by a cover letter.

Preparation of Manuscripts. Manuscripts should be typewritten, entirely double-spaced, including references, with wide margins at sides, top and bottom. All copies must be completely legible. When technical reports are submitted, all extraneous sheets and covers must be removed. Typists should check an issue of the *Annals* for style.

Submission of Reference Papers. Four copies of unpublished or not easily available papers cited in the manuscript should be submitted with the manuscript.

Title. The title should be descriptive and as concise as is feasible, i.e., it should indicate the topic of the paper as clearly as possible, but every word in it should be pertinent.

Abbreviated Title. An abbreviated title to be used as a running head is also **required**. This should normally not exceed 35 characters. For example, an article with the title "The Curvature of a Statistical Model, with Applications to Large-Sample Likelihood Methods," could have the running head, "Curvature of Statistical Model" or possibly "Asymptotics of Likelihood Methods," depending on the emphasis to be conveyed.

Affiliation. Indicate your present institutional affiliation as you would like it to appear.

Summary. Each manuscript is required to contain a summary, clearly separated from the rest of the paper, which will be printed immediately after the title. Its main purpose is to inform the reader quickly of the nature and results of the paper; it may also be used as an aid in retrieving information. The length of a summary will clearly depend on the length and difficulty of the paper, but in general it should not exceed 150 words. Formulas should be used as sparingly as possible within the summary. The summary should not make reference to results or formulas in the body of the paper—it should be self-contained.

Footnotes. Footnotes should not be used, except as described under Title Page Footnotes below. Such information should be included within the text.

Title Page Footnotes. Included as a footnote on page 1 should be the headings:

American Mathematical Society 1980 subject classifications. Primary—; secondary—.

Key words and phrases.

The classification numbers representing the primary and secondary subjects of the article may be

found with instructions for its use in the *Mathematical Reviews Annual Subject Index-1980*. The key words and phrases should describe the subject matter of the article; generally they should be taken from the body of the paper.

Acknowledgment of support. Grants and contracts should also be included in this footnote.

Identification of Symbols. Manuscripts for publication should be clearly prepared to insure that all symbols are properly identified. Distinguish between "oh" and "zero"; "ell" and "one"; "epsilon" and "element of"; "summation" and "capital sigma," etc. Indicate also when special type is required (Greek, German, script, boldface, etc.); unless indicated otherwise, formula letters will be set in italics. Acronyms should be introduced sparingly. Any handwritten symbols should be clearly identified.

Figures and Tables. Figures, charts, and diagrams should be prepared in a form suitable for photographic reproduction and should be professionally drawn twice the size they are to be printed. (These need not be submitted until the paper has been accepted for publication.) The printer does not improve upon the quality of the figures submitted. Tables should be typed on separate pages with accompanying footnotes immediately below the table.

Formulas. Fractions *in the text* are preferably written with the solidus or negative exponent; thus,

$(a + b)/(c + d)$ is preferred to $\frac{a + b}{c + d}$, and $(2\pi)^{-1}$

or $1/(2\pi)$ to $\frac{1}{2\pi}$. Also, $a^{b(c)}$ and $a_{b(c)}$ are preferred

to a^{b^c} and a_{b^c} , respectively. Complicated exponentials should be represented with the symbol exp. A fractional exponent is preferable to a radical sign.

References. References should be typed double-spaced and should follow the style:

Kiefer, J. C. (1976). Admissibility of conditional confidence procedures. *Ann. Statist.* 4 836–865.

In textual material, the format "... Keifer (1976)..." should be used. Multiple references can be distinguished as "... Keifer (1976a)..." Abbreviations for journals should be taken from a current index issue of *Mathematical Reviews*.

Addresses. The permanent address of each author should be typed following the references.

Galley Proofs. The author will ordinarily receive galley proofs. Corrected galley proofs should be sent to AOS Redactory, Science Typographers, Inc., 15 Industrial Boulevard, Medford, NY 11763.

Correspondence. All correspondence with the Editor must refer to the manuscript number of the paper. This number will be on the card sent to the author acknowledging receipt of the article.