# THE ANNALS of PROBABILITY

# AN OFFICIAL JOURNAL OF THE INSTITUTE OF MATHEMATICAL STATISTICS

#### **Articles**

Rough large deviation estimates for simulated annealing.	
Rough large deviation estimates for simulated annealing.  Application to exponential schedules	1109
Large deviations for exchangeable random vectors I. H. DINWOODIE AND S. L. ZABELL	1147
binomial mixtures and finite exchangeability	1167
Random stationary processes Kenneth S. Alexander and Steven A. Kalikow	1174
String matching: The ergodic case	1199
A note on the convergence of sums of independent random variables. ADOLF HILDEBRAND	1204
One-sided refinements of the strong law of large numbers	
and the Glivenko-Cantelli theorem DAVID GILAT AND T. P. HILL	1213
A difference prophet inequality for bounded i.i.d. variables, with cost	
	1222
On generalized renewal measures and certain first passage times GEROLD ALSMEYER	1229
Functional laws of the iterated logarithm for the increments	
of empirical and quantile processes	1248
Some large-deviation theorems for branching diffusions	1288
Limit theorems for the frontier of a one-dimensional branching diffusion	
S. LALLEY AND T. SELLKE	
Renormalization and limit theorems for self-intersections of superprocesses JAY ROSEN	
Asymptotic series and exit time probabilities W. H. Fleming and M. R. James	1369
Conditional exits for small noise diffusions with characteristic boundary .MARTIN V. DAY	1385
Quasi-invariance of product measures under Lie group perturbations:	
Fisher information and $L^2$ -differentiability  Mauro S. DE F. Marques and Luiz San Martin	1420
When does the Ramer formula look like the Girsanov formula?	1420
M. Zakai and O. Zeitouni	1436
Sur la regularité des fonctions aléatoires d'Ornstein-Uhlenbeck à valeurs	1400
dans 1 n = [1 m] X Februaries	1441
$\begin{array}{llllllllllllllllllllllllllllllllllll$	1450
An extension of Pitman's theorem for spectrally positive Lévy processes . Jean Bertoin	1464
On the distribution of the Hilbert transform of the local time	1101
of a symmetric Lévy process P. J. FITZSIMMONS AND R. K. GETOOR	1484
A note on planar Brownian motion	1498
The Stein-Chen method, point processes and compensators	
A. D. Barbour and Timothy C. Brown	1504
Clustering in the one-dimensional three-color cyclic cellular automaton ROBERT FISCH	1528
Automorphism invariant measures on trees	1549
The cycle structure of random permutations RICHARD ARRATIA AND SIMON TAVARÉ	1567
soperimetric inequalities and transient random walks on graphs Carsten Thomassen	1592
Correction	
Path properties of index-β stable fields	1601

Vol. 20, No. 3—July 1992

#### 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: Willem R. van Zwet, Department of Mathematics, University of Leiden, P.O. Box 9512, 2300 RA Leiden, The Netherlands

President-Elect: Lawrence D. Brown, Department of Mathematics, White Hall, Cornell University, Ithaca, New York 14853-7901

Past President: David O. Siegmund, Department of Statistics, Sequoia Hall, Stanford University, Stanford, California 94305

Executive Secretary: Diane M. Lambert, AT&T Bell Laboratories, 600 Mountain Avenue, Room 2C-256, Murray Hill, New Jersey 07974

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: Iain M. Johnstone, Division of Biostatistics, HRP Building, Room 10, Stanford University, Stanford, California 94305-5092

Editor, The Annals of Statistics: Michael Woodroofe, Department of Statistics, Mason Hall, University of Michigan, Ann Arbor, Michigan 48109-1027

Editor, The Annals of Probability: Burgess Davis, Departments of Mathematics and Statistics, Purdue University, West Lafavette, Indiana 47907

Editor, The Annals of Applied Probability: J. Michael Steele, Department of Statistics, University of Pennsylvania, Philadelphia, Pennsylvania 19104-6302

Executive Editor, Statistical Science: Robert E. Kass, Department of Statistics, Carnegie Mellon

University, Pittsburgh, Pennsylvania 15213

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: Roger L. Berger, Department of Statistics, Box 8203, North Carolina State University, Raleigh, North Carolina 27695

Managing Editor: Robert Smythe, Department of Statistics, George Washington University, 2201 G Street N.W., Washington, D.C. 20052.

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

Individual and Organizational Memberships. All individual members pay basic membership dues of \$40 plus \$10 for *The IMS Bulletin*. Each regular member must elect to receive at least one scientific journal for an additional amount, as follows: *The Annals of Applied Probability* (\$10), *The Annals of Probability* (\$20), *The Annals of Statistics* (\$20) or *Statistical Science* (\$10), Of the total dues paid, \$24 is allocated to The IMS Bulletin and the remaining amount is allocated equally among the scientific journal(s) received. Reduced membership dues are available to full-time students, permanent residents of countries designated by the IMS Council and retired members. Retired members may elect to receive the Bulletin only for \$20. Organizational memberships are available to nonprofit organizations at \$425 per year and to for-profit organizations at \$700 per year. Organizational 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 1992 are available to The Annals of Applied Probability (\$70), The Annals of Probability (\$80), The Annals of Statistics (\$80), The IMS Bulletin (\$45) and Statistical Science (\$70). General subscriptions are for libraries, institutions and any multiple-readership use. General subscriptions for 1992 are available to The Annals of Applied Probability (\$70), The Annals of Probability and The Annals of Applied Probability (\$180), The Annals of Statistics (\$130), The IMS Bulletin (\$50) and Statistical Science (\$75). Air mail rates for delivery outside North America are \$80 per title (excluding The IMS Bulletin).

Permissions policy. Authorization to photocopy items for internal or personal use, or the internal or personal use of specific dients, 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: 0091-1798/92 \$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 Production Editor, Patrick Kelly, Department of Statistics, University of Pennsylvania, Philadelphia, Pennsylvania 19104-6302.

The Annals of Probability (ISSN 0091-1798), Volume 20, Number 3, July, 1992. Published quarterly 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 Probability, Institute of Mathematical Statistics, 3401 Investment Boulevard #7, Hayward, California 94545.

#### EDITORIAL STAFF

Editor Burgess Davis

ASSOCIATE EDITORS

RODRIGO BAÑUELOS PETER H. BAXENDALE ERWIN BOLTHAUSEN WENDELL FLEMING DAVID GRIFFEATH GEOFFREY GRIMMETT NARESH C. JAIN STEVEN P. LALLEY GREGORY F. LAWLER TERRY LYONS PETER MAJOR MICHAEL B. MARCUS TERRY R. MCCONNELL DAVID NUALART ESA NUMMELIN GILLES PISIER
JIM PITMAN
STANLEY SAWYER
TOKUZO SHIGA
DAVID O. SIEGMUND
DANIEL W. STROOCK
RUTH J. WILLIAMS

BOOK REVIEWS PETER DONNELLY

EDITORIAL ASSISTANT MARY EPPERSON

Managing Editor Robert Smythe

PRODUCTION EDITOR PATRICK KELLY

## 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

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 Peter Ney, 1988–1990 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, 1980–1985 MICHAEL D. PERLMAN, 1983–1985 WILLEM R. VAN ZWET, 1986–1988

#### **EDITORIAL POLICY**

The main purpose of *The Annals of Probability* and *The Annals of Statistics* is to publish contributions to the theory of probability and statistics and to their applications. The emphasis is on importance and interest; formal novelty and mathematical correctness alone are not sufficient. Also appropriate are authoritative expository papers and surveys of areas in vigorous development. All papers are refereed.

#### NOTICE

Manuscripts submitted for publication in *The Annals of Probability* should be sent to the Editor at the following address:

Burgess Davis Department of Statistics Purdue University West Lafayette, Indiana 47907

#### 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 Committee on Statistics Dept of Mathematics and Dept of Decision and Information Systems 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

CORNELL UNIVERSITY Dept of Mathematics Ithaca, New York

DALHOUSIE UNIVERSITY Killam Memorial Library Halifax, Nova Scotia, Canada

FLORIDA STATE UNIVERSITY Dept of Statistics

Tallahassee, Florida

GEORGE WASHINGTON UNIVERSITY Dept of Statistics Washington, DC

HARVARD UNIVERSITY Cabot Science Library Cambridge, Massachusetts

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 Depts of Biostatistics and Mathematical Sciences 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 McGill University

Dept of Mathematics and Statistics

Montreal, Quebec, Canada

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

NORTH DAKOTA STATE UNIVERSITY LIBRARY

Fargo, North Dakota

NORTHERN ILLINOIS UNIVERSITY

Div of Statistics 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

SCOTT AIR FORCE BASE

Air Weather Service Technical Library

Scott AFB, Illinois

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

SOUTHERN ILLINOIS UNIVERSITY Dept of Mathematics and Statistics Edwardsville, Illinois

STANFORD UNIVERSITY Dept of Statistics Stanford, California

SYRACUSE UNIVERSITY Dept of Mathematics Syracuse, New York

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 CALIFORNIA Main Library Irvine, California

UNIVERSITY OF CONNECTICUT Dept of Statistics Storrs, Connecticut

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 Actuarial 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 Ellis Library Columbia, Missouri

University of Montreal Dept of Mathematics Montreal, Quebec, Canada

UNIVERSITY OF NEBRASKA Dept of Mathematics and Statistics Lincoln, Nebraska

University of New Brunswick Library Fredericton, New Brunswick, Canada

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 PENNSYLVANIA Dept of Statistics Philadelphia, Pennsylvania

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 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

WAKE FOREST UNIVERSITY
Z. Smith Reynolds Library
Winston-Salem, North Carolina

WAYNE STATE UNIVERSITY Dept of Mathematics Detroit, Michigan

YORK UNIVERSITY Dept of Mathematics Downsview, Ontario, Canada

## THE ANNALS OF PROBABILITY

#### INSTRUCTIONS FOR AUTHORS

Submission of Papers. Papers to be submitted for publication should be sent to the Editor of *The Annals of Probability*. (For current address, see the latest issue of the *Annals*.) **Three copies** should be submitted on paper that will take ink corrections, although if you do not have access to a copying machine or postage is truly prohibitive, one copy will suffice. Manuscripts will not 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. Two 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 "A Limit Theorem for Conditioned Recurrent Random Walk Attracted to a Stable Law" could have the running head, "Limit Theorem for Recurrent Random Walk" or possibly "Recurrent Random Walk Attracted to a Stable Law" depending on the emphasis to be conveyed.

**Affiliation.** Indicate your present institutional affiliation as you would like it to appear. List your permanent mailing address after the references.

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 exponen-

to  $a^{b_c}$  and  $a_{b_c}^{2\pi}$ , 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:

Révész, P. (1982). On the increments of Wiener and related processeses. *Ann. Probab.* **10** 613-622.

In textual material, the format "... Révész (1982)..." should be used. Multiple references can be distinguished as "... Révész (1982a)...". 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.

Copyright, Page Charges and Offprints. Page charges are \$45 per printed page. Payment of some or all of the estimated page charges associated with articles is strongly encouraged. The editorial review of articles and administration of page charges are completely separate activities. Manuscripts are reviewed and accepted prior to determining whether page charges will be paid.

Corresponding authors receive 25 gratis offprints. Offprints of discussion articles include the main article(s), discussion(s) and rejoinder(s) as a package. Corresponding authors of main articles receive 25 gratis offprints; corresponding discussants receive 10 gratis offprints. Additional offprints may be purchased by using the IMS Offprint Purchase Order Form accompanying the galleys.

Copyright transfer, page charges and offprints are the responsibility of the IMS Business Manager.

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