THE ANNALS of MATHEMATICAL STATISTICS

FOUNDED AND EDITED BY H. C. CARVER, 1930-1938 EDITED BY S. S. WILKS, 1938-1949

THE OFFICIAL JOURNAL OF THE INSTITUTE OF MATHEMATICAL STATISTICS

Contents

	PAGE
Rectangle probabilities for uniform order statistics and the probability that the empirical distribution function lies between two distribution functions	
G. P. Steck	1
Power bounds and asymptotic minimax results for one-sample rank tests KJELL DOKSUM AND RORY THOMPSON	12
Rejecting outliers by maximum normed residual WILHELMINE STEFANSKY	35
Errors in the factor levels and experimental design	
NORMAN R. DRAPER AND WILLIAM J. BEGGS	46
Martingale central limit theoremsB. M. Brown	5 9
Local properties of the autoregressive seriesJıří Anděl	67
An algorithm for computing the non-linear predictor JAMES B. ROBERTSON	75
Limit processes for co-spectral and quadrature spectral distribution functions IAN B. MacNeill	81
Construction of Markov processes from hitting distributions II	97
Processes obtainable from Brownian motion by means of a random time change Dennis M. Rodriguez	115
Absolute continuity and Radon-Nikodym derivatives for certain measures relative to Wiener measure	130
Randomized models and the dilution and bioassay problems	
D. A. Fraser and R. L. Prentice	141
A chi-square statistic with random cell boundaries	147
On distribution-free statistical inference with upper and lower probabilities R. J. Beran	157
On probabilities of rectangles in multivariate Student distributions: their dependence on correlations	169
Random time transformations of semi-Markov processesRICHARD F. SERFOZO	176
On bounded length sequential confidence intervals based on one-sample rank-order statistics	189
The weighted likelihood ratio, linear hypotheses on normal location parameters James M. Dickey	204
Group codes do not achieve Shannon's channel capacity for general discrete channels R. Ahlswede	224
Rates of weak convergence and asymptotic expansions for classical central limit theorems	241-
On measurable gambling problems	260
Admissibility of estimators of the mean vector of a multivariate normal distribution with quadratic loss	270
Infinitesimal look-ahead stopping rulesSheldon M. Ross	297
Continued on back	cover

Vol. 42, No. 1—February 1971

THE ANNALS OF MATHEMATICAL STATISTICS

Subscription Rates. Current issues are \$30 per volume (six issues of one calendar year). Members of the Institute of Mathematical Statistics pay different rates; see inside back cover. Single issues are \$5.75. Back numbers for all issues up to and including 1956 (Volume 27) are \$16.50 per volume, \$4.50 per issue; issues from 1957 through 1964 are \$22.00 per volume, \$5.75 per issue; from 1965 onward, \$33.00 per volume, \$5.75 per issue. Complete sets (Volumes 1 through 27) are \$275.00. If additional volumes are ordered at the same time complete sets are ordered, the price is \$16.50 per volume for Volumes 28 through 35, and \$22.00 per volume for Volumes 36 through 40. Complete sets (Volumes 1 through 40) are \$500.00.

Communications concerning subscriptions, back numbers, payment of dues, membership, changes of address, etc., should be addressed to Professor George J. Resnikoff, Treasurer, Department of Statistics, California State College, Hayward, California 94542.

Papers to be submitted for publication should be sent to the Editor, Ingram Olkin, Department of Statistics, Stanford University, Stanford, California 94305. Abstracts and corrected galley proofs should be sent to the Managing Editor, K. J. C. Smith, Department of Statistics, University of North Carolina, Chapel Hill, North Carolina 27514.

Instructions for Authors. Each manuscript is required to contain an abstract and to have a title descriptive of its contents.

The abstract will be printed immediately after the title, clearly separated from the rest of the paper. 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 an abstract will clearly depend on the length and difficulty of the paper, but in general it should not exceed 150 words. It should be typed on a separate page, under the heading "Abstract" followed by the title of the paper. Formulas should be used as sparingly as possible. The abstract should not refer to the theorems or formulas in the body of the paper—it ought to be intelligible by itself. Occasionally the abstract will make an introduction unnecessary but more often an introductory section in the paper will still be needed.

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

In the near future the *Annals* will introduce a requirement for authors to list key words and phrases and classifying numbers, as now used in publications of the American Mathematical Society. Authors may want to anticipate this requirement by including such data now.

Manuscripts should be typewritten, entirely double-spaced including references, with wide margins at sides, top and bottom. The original should be submitted with two additional copies on paper that will take corrections. Dittoed or mimeographed papers are acceptable only if completely legible. Footnotes should be reduced to a minimum, and where possible should be replaced by remarks in the text or in the references; formulas in footnotes should be avoided. References should follow the style: [5] Wilks, S. S. (1963). Multivariate statistical outliers. Sankhyā Ser. A 25 407-426.

Figures, charts, and diagrams should be professionally drawn on plain white paper or tracing cloth in black India ink, twice the size they are to be printed.

(Continued on inside back cover)

Mail to the Annals of Mathematical Statistics should be addressed to either the Editor, Managing Editor or the Treasurer, as described above. It should not be addressed to Waverly Press.

COMPOSED AND PRINTED AT THE

WAVERLY PRESS, Inc., BALTIMORE, MARYLAND 21202 U.S.A.

Second-class postage paid at Baltimore, Maryland 21202 and at additional mailing offices.

Copyright © 1971 by the Institute of Mathematical Statistics

EDITORIAL STAFF

EDITOR

INGRAM OLKIN

Associate Editors

R. L. Anderson R. R. Bahadur Peter J. Bickel David R. Brillinger L. Brown H. D. Brunk Thomas S. Ferguson RONALD K. GETOOR
S. S. GHURYE
JAROSLAV HÁJEK
W. J. HALL
JAMES F. HANNAN
DAVID L. HANSON
DONALD L. IGLEHART
J. H. B. KEMPERMAN

J. F. C. KINGMAN
JOHN W. LAMPERTI
ALBERT W. MARSHALL
JEROME SACKS
I. R. SAVAGE
FRANK L. SPITZER
HENRY TEICHER

Managing Editor

K. J. C. SMITH

PAST EDITORS OF THE ANNALS

H. C. Carver, 1930-1938S. S. Wilks, 1938-1949T. W. Anderson, 1950-1952

T. E. HARRIS, 1955-1958
WILLIAM KRUSKAL, 1958-1961
J. L. HODGES JR., 1961-1964

E. L. LEHMANN, 1953-1955

D. L. Burkholder, 1964-1967

Z. W. BIRNBAUM, 1967-1970

Published bimonthly by the Institute of Mathematical Statistics in February, April, June, August, October and December.

EDITORIAL POLICY

The main aim of the Annals of Mathematical Statistics is to publish original contributions to theoretical statistics and to probability theory. The emphasis is on quality, not just on formal novelty and correctness of the contents of a paper. Expository papers are also welcome, especially if they provide authoritative surveys of areas that have been in vigorous development.

IMS INSTITUTIONAL MEMBERS

AEROSPACE CORPORATION

El Segundo, California

THE AMERICAN COLLEGE TESTING PROGRAM IOWA City, IOWA

ARIZONA STATE UNIVERSITY

Tempe, Arizona

ARTHUR D. LITTLE, INC.

Cambridge, Massachusetts

BELL TELEPHONE LABORATORIES, TECHNICAL LIBRARY

New York, New York

BOEING SCIENTIFIC RESEARCH, LABORA-TORIES

Seattle, Washington

CASE WESTERN RESERVE UNIVERSITY, DE-PARTMENT OF MATHEMATICS

Cleveland, Ohio

CATHOLIC UNIVERSITY OF AMERICA, STA-TISTICAL LABORATORY

Washington, D.C.

CHEVRON RESEARCH COMPANY Richmond, California

CIBA PHARMACEUTICAL COMPANY

Summit, New Jersey

COLORADO STATE UNIVERSITY, STATISTICAL LABORATORY
Fort Collins, Colorado

Cornell University, Department of Mathematics

Ithaca, New York

FLORIDA STATE UNIVERSITY, DEPARTMENT OF STATISTICS Tallahassee, Florida

FORD MOTOR COMPANY, SCIENTIFIC LAB-ORATORIES Dearborn, Michigan

GENERAL MOTORS CORPORATION, RESEARCH LABORATORIES

Warren, Michigan

GEORGE WASHINGTON UNIVERSITY, DE-PARTMENT OF STATISTICS

Washington, D.C.

INDIANA UNIVERSITY, THE LIBRARY Bloomington, Indiana

INTERNATIONAL BUSINESS MACHINES COR-

Armonk, New York

IOWA STATE UNIVERSITY, STATISTICAL LABORATORY
Ames, Iowa

JOHNS HOPKINS UNIVERSITY, DEPARTMENT OF BIOSTATISTICS, DEPARTMENT OF STATISTICS
Baltimore, Maryland

KANSAS STATE UNIVERSITY, DEPARTMENT OF STATISTICS

Manhattan, Kansas
KENT STATE UNIVERSITY, DEPARTMENT OF
MATHEMATICS

Kent, Ohio

KNOLLS ATOMIC POWER LABORATORY Schenectady, New York

MIAMI UNIVERSITY, DEPARTMENT OF MATHEMATICS Oxford, Ohio 45056

MICHIGAN STATE UNIVERSITY, DEPARTMENT OF STATISTICS

East Lansing, Michigan

MINNESOTA MINING AND MANUFACTURING COMPANY, APPLIED MATHEMATICS AND STATISTICS

Saint Paul, Minnesota

NATIONAL SECURITY AGENCY

Fort George G. Meade, Maryland

NEW MEXICO STATE UNIVERSITY, DEPART-MENT OF MATHEMATICAL SCIENCES Las Cruces, New Mexico

NORTHWESTERN UNIVERSITY, DEPARTMENT OF MATHEMATICS

Evanston, Illinois

Ohio State University, Department of Mathematics, Statistical Laboratory

Columbus, Ohio

OKLAHOMA STATE UNIVERSITY, DEPART-MENT OF MATHEMATICS AND STATISTICS Stillwater, Oklahoma

OREGON STATE UNIVERSITY, DEPARTMENT OF STATISTICS

Corvallis, Oregon

PENNSYLVANIA STATE UNIVERSITY, DE-PARTMENT OF MATHEMATICS LIBRARY University Park, Pennsylvania

PRINCETON UNIVERSITY, DEPARTMENT OF STATISTICS

Princeton, New Jersey

PURDUE UNIVERSITY LIBRARIES

Lafayette, Indiana

THE RAND CORPORATION Santa Monica, California

Santa Monica, California

THE ROCKEFELLER UNIVERSITY New York, New York

ROCKLAND STATE HOSPITAL, RESEARCH CENTER

Orangeburg, New York

SANDIA CORPORATION, SANDIA BASE Albuquerque, New Mexico

SIMON FRASER UNIVERSITY, DEPARTMENT OF MATHEMATICS

Burnaby, British Columbia, Canada

SOUTHERN METHODIST UNIVERSITY, DE-PARTMENT OF STATISTICS Dallas, Texas

STANFORD UNIVERSITY, GIRSCHICK MEMORIAL LIBRARY
Stanford, California

STATE UNIVERSITY OF NEW YORK, BUFFALO,
DEPARTMENT OF STATISTICS
Amherst, New York

System Development Corporation Santa Monica, California

TEXAS A & M UNIVERSITY, INSTITUTE OF STATISTICS College Station, Texas THE TOBACCO INSTITUTE Washington, D.C.

UNION OIL COMPANY OF CALIFORNIA, UNION RESEARCH CENTER Brea, California

UNITED STATES ARMY RESEARCH AND DE-VELOPMENT CENTER

Aberdeen Proving Ground, Maryland

UNITED STATES STEEL CORPORATION, AP-PLIED RESEARCH LABORATORY Monroeville, Pennsylvania

University of Alberta, Department of MATHEMATICS

Edmonton, Alberta, Canada

UNIVERSITY OF ARIZONA, DEPARTMENT OF MATHEMATICS Tucson, Arizona

University of British Columbia, De-PARTMENT OF MATHEMATICS Vancouver, B.C., Canada

University of California, Berkeley, STATISTICAL LABORATORY Berkeley, California

University of California, Department OF MATHEMATICS

Davis, California

University of California, Department OF MATHEMATICS Irvine, California

University of California, School of Public Health

Los Angeles, California

University of California, Department OF MATHEMATICS Riverside, California

University of California, Department OF MATHEMATICS Santa Barbara, California

University of Guelph, Library, Serials DEPARTMENT

Guelph, Ontario, Canada

UNIVERSITY of Illinois AT CHICAGO CIRCLE, DEPARTMENT OF MATHEMATICS Chicago, Illinois

University of Illinois, Library, Serials DEPARTMENT Urbana, Illinois

University of Iowa, Division of Mathe-MATICAL SCIENCES

Iowa City. Iowa

University of Manitoba, Department OF STATISTICS

Winnipeg-19, Manitoba, Canada

University of Maryland, Department OF MATHEMATICS

College Park, Maryland

UNIVERSITY OF MASSACHUSETTS, DEPART-MENT OF MATHEMATICS & STATISTICS Amherst, Massachusetts

University of Michigan, Department of MATHEMATICS

Ann Arbor, Michigan

UNIVERSITY OF MINNESOTA, DEPARTMENT OF STATISTICS

Minneapolis, Minnesota

University of Missouri, Department of STATISTICS Columbia, Missouri

UNIVERSITY OF MISSOURI AT ROLLA, DE-PARTMENT OF MATHEMATICS Rolla, Missouri

University of Montreal, Department OF MATHEMATICS

Montreal, Quebec, Canada

University of New Mexico, Department OF MATHEMATICS & STATISTICS Albuquerque, New Mexico

University of North Carolina, Depart-MENT OF STATISTICS Chapel Hill, North Carolina

UNIVERSITY \mathbf{OF} PENNSYLVANIA, THE LIBRARY

Philadelphia, Pennsylvania

University of Puerto Rico, Depart-MENT OF MATHEMATICS Mayaguez, Puerto Rico

University of Rochester

Rochester, New York

University of Washington, Laboratory OF STATISTICAL RESEARCH Seattle, Washington

UNIVERSITY OF WISCONSIN, MADISON, DE-PARTMENT OF STATISTICS

Madison, Wisconsin

University of Wisconsin, Milwaukee. DEPARTMENT OF MATHEMATICS Milwaukee, Wisconsin

WAYNE STATE UNIVERSITY, DEPARTMENT OF MATHEMATICS Detroit, Michigan

WEST CHESTER STATE COLLEGE West Chester, Pennsylvania

WESTAT RESEARCH, INC. Bethesda, Maryland

WESTINGHOUSE ELECTRIC CORPORATION, RESEARCH LABORATORIES Pittsburgh, Pennsylvania

MEETINGS OF THE INSTITUTE

NOTE: This calendar lists all of the meetings which have been approved by the IMS Council to date. Meeting dates which fall rather far in the future are subject to change.

Meet- ing No.	Place	Date	Abstract Deadline*	Joint With
131	Fort Collins, Colorado (Annual)	August 23–26, 1971	June 24, 1971	ASA
	Blacksburg, Virginia (Eastern Regional)	Spring 1972		ASA
	Ames, Iowa (Central Regional)	Spring 1972		ASA, ENAR
	Seattle, Washington (Western Regional)	Spring 1972		
	Ithaca, New York (Eastern Regional)	Spring 1973		ASA, ENAR
	Albuquerque, New Mexico (Western Regional)	Spring 1973		

^{*} Abstracts should be submitted in duplicate to the Managing Editor, K. J. C. Smith, Department of Statistics, University of North Carolina, Chapel Hill, North Carolina 27514, on abstract blanks which may be obtained from him. Abstracts of papers to be presented in person at the meetings must be received on or before the corresponding deadline. Only one contributed paper may be given in person at any one meeting. Abstracts contributed by title may be submitted at any time and will be printed in the next issue to go to press. Abstracts should not exceed 200 words and should avoid displayed expressions and complicated formulae. They can be accepted from non-members of the IMS only if introduced by members. Abstracts must follow the stylistic requests on the abstract blank or they may be returned.