UBC

STATISTICS

DEPARTMENT

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CO-ORDINATOR - Nancy Heckman
DESIGN, LAYOUT - Heather Aston Moore
PHOTOGRAPHY - Bob Jemison, Warren Schmidt
DESKTOP PUBLISHING - Pat Fornelli
TYPING - Mary Rodgers

Department of Statistics
2021 West Mall
University of British Columbia
Vancouver, B.C. V6T 1W5
Canada

THE UNIVERSITY

The University of British Columbia has an enrolment of 27,000 students, 3800 of whom are in the Faculty of Graduate Studies. The campus, located twelve kilometres from downtown Vancouver, is noted for its scenic setting and mountain views. The University Endowment Lands, which border campus, are forested, with many hiking trails. In spite of the proximity to mountains and snow, the climate in Vancouver is mild in winter, although the temperature occasionally drops below freezing

THE DEPARTMENT

The Department of Statistics, in the Faculty of Science, was formed in 1983. At present the Department consists of nine regular faculty members (including two with joint appointments in the Faculty of Medicine), two Professor Emeriti, four Associate Members in Mathematics, Commerce, and the Institute of Animal Resource Ecology, two adjuncts, at the Pacific Biological Research Station and the Cancer Control Agency of B.C., and ten graduate students.

While the orientation of the Department is theoretical, most members have a strong interest in applications of statistics. This manifests itself not only through the links with other UBC departments as mentioned above, but also through the importance placed upon the Department's Statistical Consulting and Research Laboratory (SCARL) and through the Department's work on the analysis of acid deposition data funded through a grant from the United States Environmental Protection Agency.

In addition to the Department's weekly seminar, there are regular environmetrics meetings and weekly discussion sessions attended by all of those involved in SCARL.

FACULTY MEMBERS AND THEIR MAJOR FIELDS OF INTEREST

(AS) associate, (AD) adjunct, (E) emeritus

Coldman, Andrew (AD)
Biostatistics, models for development of resistance to anticancer agents

De Jong, Piet (AS)
Time series analysis, applied statistics

Delampady, Mohan
Robustness in testing and estimation, Bayesian nonparametric estimation

Glick, Ned
Statistical discrimination, classification and pattern recognition, record values, statistics in medicine

Greenwood, Priscilla (AS)
Stochastic processes and asympotic inference for stochastic processes

Heckman, Nancy
Nonlinear renewal theory, sequential design of experiments, nonparametric regression, spline smoothing

Joe, Harry
Statistical inference, applied probability, multivariate dependence, density estimation

Liu, Jian
Time series

Ludwig, Donald (AS)
Fisheries management, computer-aided analysis of data

Marshall, Albert (E)
Inequalities, multivariate distribution theory, reliability theory

Nash, Stanley (E)
Design and analysis of experiments, multivariate analysis

Petkau, A. John
Bayes sequential decision problems, optimal design of clinical trials, sequential methods, statistical consulting

Puterman, M.L. (AS)
Medical statistics, regression analysis, dynamic programming

Schnute, Jon (AD)
Resource management, fisheries, stochastic modelling

Schulzer, Michael
Medical statistics

Zamar, Ruben
Bias robust estimates

Zidek, James V.
Statistical decision theory, environmental monitoring, network design, data analysis

M.Sc. PROGRAM

The M.Sc. program normally takes two years for completion, although students with strong backgrounds in both statistics and mathematics may be able to complete it in one year.

The principle objective of the M.Sc. program is to train students for positions as statisticians in government and industry, but the program can also serve as preparation for students wishing to undertake work towards a Ph.D. degree in Statistics. A thesis is required; for most students this will consist of a report of applied statistical work. This work may be undertaken as a project or projects for the Statistical Consulting and Research Laboratory, the Acid Rain Project, or occasionally for an agency outside the University. Students are expected to give a presentation of their thesis work in an informal seminar. There are no examinations other than course examinations.

Students seeking an M.Sc. in Statistics should have an undergraduate background in both mathematics and statistics, and possibly a few courses in computer science.

Ph.D. PROGRAM

Statistics students will normally be accepted as Ph.D. candidates only after they have received an M.Sc. in Statistics. The Ph.D. program typically involves 3-4 years of study beyond the M.Sc. but a student with a strong undergraduate background in mathematics and statistics (including courses in linear algebra, real analysis, linear models and mathematical statistics) may be able to complete both the Master's and Ph.D. program in 4 years. No formal course requirements are specified beyond the M.Sc. level, but students should take a sufficient number of courses to insure a broad exposure to both graduate level statistics and mathematics.

Students are expected to take a qualifying exam within their first year. After passing this examination, the student should decide on an area for thesis research and find a supervisor. Within the first two years, a comprehensive oral exam must be taken based on Statistics 519, Mathematics 518 (Probability), and two advanced areas of specialization. At the conclusion of his/her research, the student must defend it at an oral examination given by the Faculty of Graduate Studies. Each student must demonstrate, by translating one journal article, a reading knowledge of at least one approved language, other than English.

COURSE OFFERINGS

The following courses are offered on a regular basis by the Statistics Deparment. (Not all courses are offered every year.) Courses in probability are offered by the Mathematics Department.

519 Theoretical Statistics
520 Statistical Decision Theory
521 Foundations of Multivariate Analysis
522 Asymptotic Theory and Conditional Inference
530 Bayesian Inference and Decision
531 Reliability Theory
532 Sequential Statistical Procedures
533 Survival Analysis
534 Statistics in Quality Control
541 Applied Multivariate Analysis
542 Analysis of Categorical Data
543 Time Series Analysis
544 Theory of Sampling
545 Data Analysis
546 Nonparametric Statistical Methods
547 Topics in Statistics (recent offerings have included Statistical Computing, Robust Statistics)
550 Techniques of Statistical Consulting
551 Statistical Consulting

ADMISSIONS PROCEDURE

Students wishing to enter the program in September should apply by mid-March. Application forms and further information are available from:

Graduate Committee
Department of Statistics
2021 West Mall
University of British Columbia
Vancouver, B.C. V6T 1W5
Canada

FINANCIAL AID

All applicants are automatically considered for teaching and research assistantships. A teaching assistant is usually assigned to grade papers and/or conduct problem sessions. Research assistantships are typically funded by SCARL or the Acid Rain Project.

National Sciences and Engineering Research Council graduate fellowships are available to Canadian citizens and landed immigrants. Applications for these awards, funded by the Canadian government, must be made through the Department.

University Graduate Fellowships are available to both Canadian and foreign students. Applications, due in February, are made through the Department.

STATISTICAL CONSULTING AND RESEARCH LABORATORY (SCARL)

The Statistical Consulting and Research Laboratory (SCARL), operated by the Department of Statistics, provides statistical advice to researchers on the UBC campus as well as, selectively, to off-campus researchers. Assistance is offered in the formulation of research questions, the design of experiments and surveys, explanations of statistical methodology, analysis and interpretation of findings, statistical computing and graphics, and preparation of grant proposals. SCARL's clients come from a wide range of disciplines including medicine, nursing, pharmacy, dentistry, psychology, social work, geology, resource ecology, engineering, and geography.

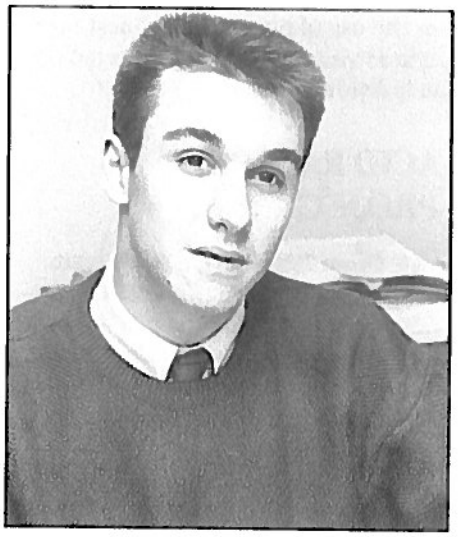
Although some consultations are brief discussions or routine applications of statistical computing packages, in-depth collaborative research and long-term projects are particularly encouraged.

Through such collaborations, SCARL assists in the professional development of Faculty and in the training of graduate students in the Department of Statistics. SCARL works in conjunction with graduate courses in statistical consulting. In addition, graduate students are involved as research assistants at all levels of projects, from meeting with clients to analyzing their data and producing final reports. Some of these projects develop into M.Sc. research theses for Statistics students. Most faculty members are involved to varying degrees, and undertake problems of particular interest to them. Faculty and graduate students meet weekly to review and discuss current and future work.

SCARL plays an active role in continuing education on and off campus, giving seminars and workshops to various departments, research groups, and teaching hospitals, all involved in quantitative research. Seminars on topics of interest to particular groups of researchers provide an effective way of introducing them to the scope of services and expertise provided by SCARL, in addition to enhancing their awareness of some of the principles of good experimental design and of recent advances in statistical methodology.

The daily operations of SCARL are run by the Coordinator and by the Managing Consultant, Peter Schumacher, who also looks after the computing facilities in the Department. State-of-the-art computing hardware and software permits research which would be prohibitively expensive on the University's central facilities. In addition, it encourages students to experiment with statistical packages and novel techniques, sometimes of their own devising.

The SCARL office is always a hub of activity, and interested persons are encouraged to enquire about current work or browse through reports prepared as part of past projects.



Peter Schumacher

MANAGING CONSULTANT, SCARL

B.A. (1983), University of Toronto

M.Sc. (1986), The University of British Columbia

The University of British Columbia (1985-present)

RESEARCH INTERESTS

As an undergraduate, I studied applied mathematics and economics. My M.Sc. degree, through UBC's Faculty of Commerce, was in management science, with a concentration in statistics. In my thesis, under the direction of Professor M. Puterman (an Associate Member of the Statistics Department), I studied problems related to the safe monitoring of the toxic side effects of Adriamycin, a drug used in the treatment of cancer. This work involved an interesting combination of techniques drawn from statistics and integer programming. My interest in applied statistics continues and, through my work at SCARL, my interest has broadened to include statistical computing.

My job as Managing Consultant of SCARL involves many different activities. Often, I must find ways to explain statistical methods to SCARL clients who have little background in statistics, but must make use of these methods in their research. Of course, sometimes the appropriate statistical method for a particular study isn't immediately clear. In this case, I must do a little research and/or discuss the problem with other members of the Department. In addition to my consulting duties, I am responsible for maintaining the computing facilities of the Department. This involves anything from getting the new Apple Laser Writer to produce reasonable output to providing on-line documentation for the various software packages available.

PUBLICATIONS

Sandor, Schumacher, Puterman, and Popov (1987). Normal serial variability for M-mode digitized echocardiography in a pediatric population. *Pediatric Cardiology*, 8:3-26.

COMPUTING FACILITIES

HARDWARE

The Department of Statistics owns a Digital Equipment MicroVax II, a 32-bit "superminicomputer" nicknamed EMILY. It has 3-Mb of core memory, three 71-Mb hard disks, a 95-Mb cartridge tape drive, and 16 peripheral ports. One port is devoted to an Apple Laser Writer printer, one to a CIE CI-3500 dot matrix printer, and two ports serve as connections to the UBC NIM (Network Interface Machine). The remaining ports are set aside for user terminals.

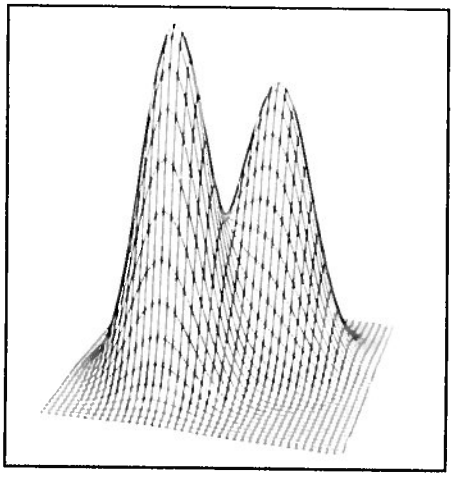
Besides three terminals and three connected PC's located in faculty offices and the SCARL office, there are four terminals for general access; one has graphics capabilities, and its own plotter. These are for the use of Department faculty and graduate students. Another two graphics terminals will be acquired soon.

The 9600-baud hardwired link to the NIM means that one can use the MicroVax as a dummy terminal on MTS (the UBC mainframe) or on the BioSciences Data Centre's VAX 11/750. Most terminals also have a separate port to the NIM. At present it is not possible to call into the MicroVax from the NIM.

The Department has recently purchased two PC's: an Apple Mac II and an IBM XT-compatible.

SOFTWARE

The MicroVax runs under Ultrix, an operating system very close to the Berkeley 4.2 Unix. Besides C, Pascal and Fortran compilers and the Slatec Math Library, there are a number of specialized statistical programs available, to perform Generalized Linear Modelling (GLIM), Alternating Conditional Expectations (ACE), Kriging, Classification and Regression Tree Analysis (CART), Nonlinear Programming, to name a few. The computer mathematical typesetting environment "TeX" is also fully supported.



The probability density function of the mixture of two bivariate normals, as drawn in S.

The primary statistical environment is "S", from Bell Labs. S is a large and very powerful system, supporting APL-type matrix algebra: arithmetic operations, (generalized) matrix inversion, eigenanalysis, Kronecker operations, Cholesky decomposition; standard mathematical functions and utilities: trigonometric, transcendental and gamma functions, ranking, sorting and ordering, Boolean operations; statistical functions: Regression, Cluster Analysis, Multi-Dimensional Scaling, Discriminant Analysis, Time Series Analysis; and random number generation from a list of common distributions.

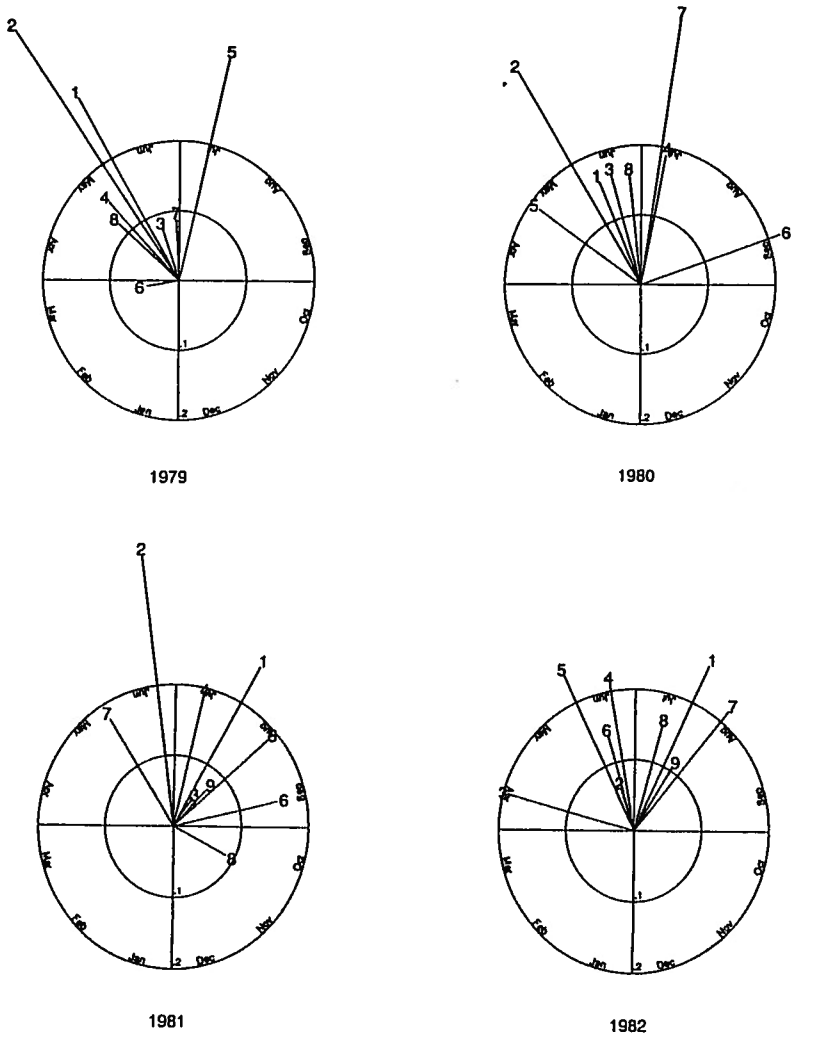
S also has extensive graphics capability, with point labelling, contour generation, three-dimensional perspective plots, Chernoff faces, histograms, quantile-quantile and box plots, bar plots, pie charts, and smoothing density estimation. Instead of providing many standard statistical analyses prepackaged, S encourages the user to develop his or her own analysis and associated functions using the existing math and graphics capabilities. Our graduate students and faculty have found S a useful and easy-to-learn tool in their work.

Lastly, there are file transfer facilities between the MicroVax and other UBC machines, and facilities for sending electronic mail reliably anywhere in the world. There are at present no charges to faculty and students of the Department of Statistics for the use of our system. Guest users, such as visitors, may be supported on an individual basis.

ACID RAIN (SIMS) PROJECT

From 1984-1987, a study team centered in the Department of Statistics at UBC participated in a $1-million three year study on acid rain, an environmental problem which is plaguing North America, Europe and other parts of the world. Funding for this study was renewed for another three years in 1988. The project began in 1984/85 when a team of six investigators from the Universities of British Columbia and Washington joined with groups from Stanford University and the Rand Corporation in making application, co-ordinated by the SIAM Institute for Mathematics in Society (SIMS), an agency of the Society for Industrial and Applied Mathematics, to the Environmental Protection Agency of the United States for a Co-operative Research Agreement to study statistical problems associated with acid rain. Principal investigators of the UBC team, both from the Department of Statistics, are Dr. A.J. Petkau and Department head, Dr. J.V. Zidek. Other members of the original UBC study team involved in making this application were Drs. A.W. Marshall and W. Caselton of the Departments of Statistics and Civil Engineering respectively at UBC and Drs. P. Guttorp and P. Sampson of the Department of Statistics at the University of Washington. Since that time, Drs. H. Joe, M. Delampady and R. Zamar of the Department of Statistics have joined the study team and a number of visitors to the Department have participated to varying extents.

Acid rain is caused when substances in emissions from industry and other sources undergo chemical reactions in the atmosphere, are converted to acids and fall to the earth. Although acid rain may well have a substantial effect on the environment, its sources are unclear; in particular, how much of it is the result of industry and other human activities, and how much of it is natural



Phases and amplitudes of seasonal pH variation from acid deposition data collected in the MAP3S/PCN network in the northeastern United States.

is uncertain. The precise measurement of the impact of acid rain, necessary for regulation and control, is exceedingly difficult. The solutions involve mathematical and statistical problems of great variety and depth. The study team aims to estimate the naturally-caused levels of acid rain as a fraction of the total amount present in any location. In particular, statistical methods are being developed to allow for the detection of the impact of acid rain, to measure trends, to map acid rain deposition levels, and to determine how those levels vary from region to region.

A deposition process may be regarded as carrier + noise, where the carrier = model + smooth and the smooth is locally approximable by its Taylor expansion. Bayes and empirical Bayes methods of estimating the smooth have been extensively studied for Gaussian deposition fields by Drs. Joe, Weerahandi, Zidek and Mr. Hon Ma , a former M.Sc. student who graduated in autumn 1986. Dr. Delampady is currently studying the problem of Bayesian estimation of the carrier, and Dr. Zamar is applying techniques of robust estimation to the problem.

The ability to estimate extreme values of atmospheric contaminants is vital in any problem of regulation, control and abatement; research in this direction was undertaken by Dr. H. Joe. The problem is to estimate quantiles of the maximum of a sequence of N random variables (say, a future time series) given that n observations have been obtained. Research has been done in the case where the random variables are assumed independent and identically distributed; two parametric approximations from asymptotic extreme value theory were compared. Future research will deal with the case of weakly dependent observations, this being a more realistic assumption for practical application.

In setting guidelines for regulation it is becoming increasingly common to convene a group of experts to search for a consensus. They may be asked to reach a consensual decision. A celebrated, normative, equilibrium solution to such a group decision problem is provided by Nash's theory: the equilibrium solution maximizes a certain functional of the individual utility functions. Software has been developed by Mr. Mark Wells, a work-study student working under the supervision of Dr. Zidek, to plot for the case of $n = 3$ experts, the region of achievable utility vectors when a common estimate of a vector of multinormal mean levels is at issue. From this it is possible to see precisely how dissension (when the equilibrium becomes a randomized decision rule) is reached as preferences and opinions of the experts diverge.

An expert's opinion about the possible states of nature, the uncertain site of a point impact, for example, or its level, may be quantified as a probability distribution. Each of a group of experts would generate such a distribution. A formula for combining these distributions and hence their underlying opinions has been derived by Dr. C. Genest, Dr. S. Weerahandi, both visitors and Dr. Zidek.

Work on the project is organized around biweekly working sessions where ongoing research is discussed and ideas are exchanged. These working sessions have provided a convenient mechanism for involving students in research activities related to the study at an early stage of their graduate programs. In addition, a seminar series facilitates the exchange of knowledge on acid rain in particular, and environmetrics in general, among researchers in government, industry and universities.

Mohan Delampady

ASSISTANT PROFESSOR

B.S. (1981), Indian Statistical Institute

M.S. (1982), Indian Statistical Institute

Ph.D. (1986), Purdue University

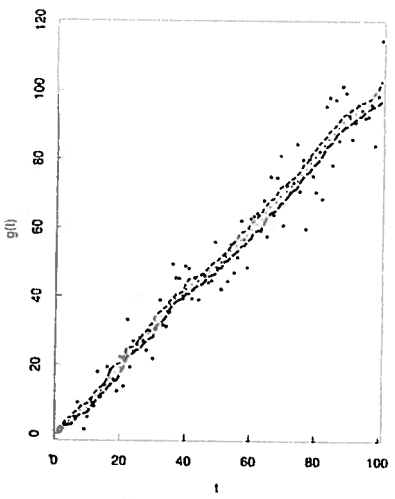
The University of British Columbia (1986-present)

RESEARCH INTERESTS

My research involves the Bayesian approach to statistical inferences. I am especially interested in nonparametric estimation of functions, and in prior and model robustness of estimation and testing.

Bayesian nonparametric estimation using priors on function spaces is an exciting field of research. Usually the unknown function is modelled as a stochastic process having support in an appropriate function space (Delampady 1987a). This approach is closely related to nonparametric smoothing techniques.

Sensitivity of statistical procedures to the assumptions under which they are derived is of great interest. For a Bayesian, assumptions regarding the model as well as the prior distribution are of concern. The study of sensitivity utilizing large classes of prior and model densities is showing considerable promise (Berger and Delampady, 1987, Delampady, 1987b).



Pointwise Bayesian confidence band for a monotone regression function.

SELECTED PUBLICATIONS

Berger, J. and Delampady, M. (1987). "Testing precise hypotheses." *Statistical Science*, 2:317-334.

Delampady, M. (1987a). "Estimating a monotone regression function." Presented at the Third Valencia International Meeting on Bayesian Statistics.

Delampady, M. (1987b). "A robustness analysis: credible regions and hypothesis test for elliptical distribution". Technical report #55, Department of Statistics, University of British Columbia.

Ned Glick

ASSOCIATE PROFESSOR

A.B. (1964), Oberlin College

Ph.D. (1969), Stanford University

Research Associate (Assistant Professor), University of Chicago (1968-70)

The University of British Columbia (1970-present)

RESEARCH INTERESTS

I have been interested in various methodologic issues (and occasionally theorems) that arise in planning and data analysis for particular projects. For instance, a comparison between brand-name and generic drugs may lead to general questions about how to assess "bio-equivalence". Or a dispute concerning the counting of certain items may raise general questions of how to assess agreement between two observers. Discussions about the setting of standards for structural lumber once led me to study sequential specimen examination; and later thinking about record high or low strengths of boards in such examination led to my interest in probability theory of record values.

Most of my statistical consulting is with researchers in various University departments or from affiliated medical institutions, with perhaps several dozen such consultations each year. For example, in recent years, I have cooperated with hospitals and clinics in evaluations of innovative maternal and baby health programs (midwife roles, immunization, promotion of automobile safety seats).

I have long-standing interest in statistical discrimination and classification procedures. These procedures have been increasingly applied in medicine, not only for individual assessment or prediction ("diagnosis" and "prognosis"), but also for epidemiologic identification of low-risk and high-risk groups. Although diagnostic and epidemiologic procedures may be equivalent in mathematical formulation, context may be quite relevant to methodologic decisions, including selection among computational options in well-known software packages. Other methodologic issues in statistical classification concern the estimation of a procedure's success or error rates: over the past two decades optimistic bias of "apparent" rates of "re-substitution" (using the same data both to design and to evaluate a procedure) was first noticed empirically and only later understood mathematically -- and the tendency of bias correction techniques to increase variance still is not widely understood.

Currently, I am trying to re-think some familiar, basic statistical methods from the perspective of contemporary computing capabilities. For example, many statistical programmers have translated formulas for various test statistics into FORTRAN or BASIC or Pascal code that computes numeric results just as a person would compute the formulas (only faster and with more digits). However, algorithms which may involve iteration, branching, or recursive functions may be faster, more general, and closer to real methodologic insight. One algorithm may unify a half-dozen formulas for procedures that are named after different statisticians and that look very different as formulas. More profoundly, the historic preference for parametric tests rather than non-parametric confidence intervals may be due largely to existence of simple -- and perhaps now obsolete -- formulas for those parametric tests.

SELECTED PUBLICATIONS

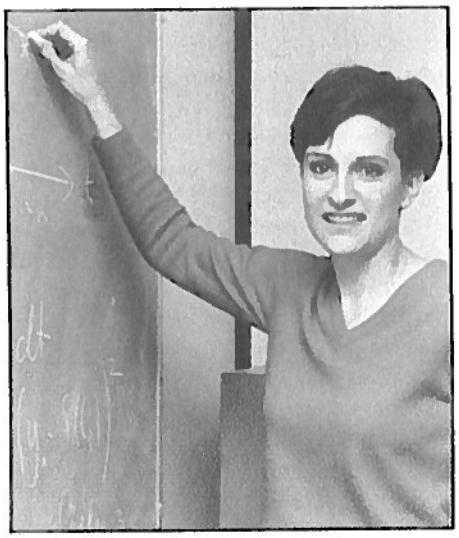
Glick, Ned (1970). "Hijacking Planes to Cuba: An up-dated version of the birthday problem." *American Statistician*, **24**:41-44.

Glick, Ned (1974). "Consistency conditions for probability of correct classification among two or more distributions." *Utilitas Mathematica,* **6**:61-74.

Glick, Ned (1978). "Breaking records and breaking boards." *American Mathematical Monthly*, **85**:2-26.

Glick, Ned (1978). "Additive estimators for probabilities of correct classification." *Pattern Recognition*, **10**:211-222.

Vertesi, L., Wilson, L. and Glick, N. (1983). "Cardiac arrest: comparison of-paramedic and conventional ambulance services." *Canadian Medical Association Journal*, **128**:809-813.



Nancy E. Heckman

ASSISTANT PROFESSOR

B.S. (1977), Tufts University

M.A. (1982), University of Michigan, Ann Arbor

Ph.D. (1982), University of Michigan, Ann Arbor

Assistant Professor, State University of New York, Stony Brook (1982-1984)

The University of British Columbia (1984-present)

RESEARCH INTERESTS

My research interests include the sequential design of medical experiments and nonparametric regression.

In a medical study to compare the effects of two treatments, if each subject receives only one of the two treatments, determining a statistically appropriate method of treatment assignment is crucial. The method should satisfy two criteria: the subjects should be assigned in such a way as to allow an accurate estimate of the difference in treatments (e.g., half of the subjects should receive each treatment) and the assignments should be done in a random way, to avoid the possibility of personal biases affecting the study. These two criteria are, in some sense, conflicting, since the first criterion is a deterministic one, while the second is non-deterministic. This conflict is difficult to resolve if human subjects are used, because the subjects typically enter the study one at a time and must be assigned to a treatment immediately. That is, one can't put all of the subjects' names in a hat and draw half of them for assignment to one treatment, since all of the names are not available until after assignments must be made. Many people, myself included, have studied this problem in very simple statistical models.

Of course, how one models treatment response will influence what one considers a good assignment method. If a model involves many rigid assumptions and if the treatment responses do not satisfy the postulated model exactly, then the supposedly "good" assignment method might be completely inappropriate. In particular, if the response depends on some covariate, such as age, one is led to consider nonparametric regression techniques involving, for instance, splines or kernels. An interesting modification of the assumptions of nonparametric models is found in the semiparametric model, in which response to one treatment is some unknown, but smooth function of a covariate, while the response to the other treatment is just that unknown function plus a constant. My work in this area includes the derivation of estimates of the constant and studying properties of these estimates through theoretical methods and via computer simulations.

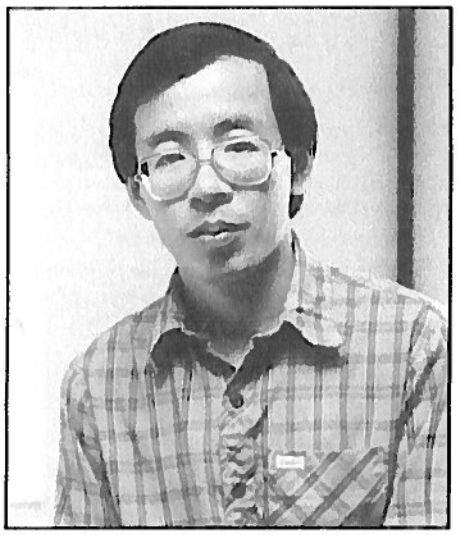
SELECTED PUBLICATIONS

Heckman, N. (1986). "Spline smoothing in a partly linear model." *Journal of the Royal Statistical Society B,* **48**:244-248.

Heckman, N. (1986). "Repeated significance tests with biased coin allocation schemes." *Probability Theory and Related Fields,* **73**:627-635.

Heckman, N. (1987). "Robust design in a two treatment comparison in the presence of a covariate." *Journal of Statistical Planning and Inference,* **16**:75-81.

Heckman, N. (1988). "Minimax estimates in a semiparametric model." *Journal of the American Statistical Association.*



Harry Joe

ASSOCIATE PROFESSOR

B.Sc. (1978), University of Victoria

M.Sc. (1979), The University of British Columbia

Ph.D. (1982), Florida State University

The University of British Columbia (1982-present)

RESEARCH INTERESTS

My research interests are in many areas of statistics. These include use of majorization and entropy in statistics, measures of multivariate dependence, density estimation, paired comparisons, inference for extreme values.

Majorization is an ordering of dispersion among vectors with the same sum of components, with a constant or uniform vector being at the low end of the ordering. It can, for example, be used to compare probability vectors, in which case it is an ordering of entropy; Shannon entropy and other entropy functions are decreasing with respect to majorization. My research has involved a study of a generalized majorization for arbitrary probability densities and a study of constrained majorization over a class of probability distributions or other objects with constraints. Examples of generalized majorization include continuous majorization and divergence from an arbitrary positive non-uniform vector. Examples of constrained majorization include:

(a) bivariate probability distributions with fixed univariate marginal distributions,

(b) probability distributions of k-tuples with fixed univariate marginals,

(c) probability matrices associated with paired comparisons,

(d) probability distributions with fixed moments.

For examples (a) and (b), majorization can be interpreted as an ordering of dependence. Example (b) has applications to lotteries such as Lotto 6/49: the majorization theory can be used to get rough estimates of the distribution of 6-tuples chosen by lottery ticket buyers based on the published marginal frequency of each number from 1 to 49. Example (c) (in which majorization can be interpreted as an ordering of transitivity) and its generalization have application to estimating pairwise winning proportions and pairwise average goal spreads from season standings for such sports as baseball and hockey. Example (d) has application to prior probabilities in that qualitative results can be obtained for distributions with given moments that are closest to a subjective or invariant prior. There is a close connection between minimal objects with respect to constrained majorization and the maximum entropy principle and the principle of minimum cross entropy.

Majorization as an ordering of dependence has led to consideration of relative entropy measures of multivariate dependence and conditional dependence, which are increasing with respect to the majorization ordering. These measures are for dependence among 2 or more different quantities which can be continuous (quantitative) or categorical (qualitative) and can be viewed as nonparametric generalizations of the correlation, multiple correlation and partial correlation measures for linear regression models. They have potential application to nonparametric regression. For data, computation of the measures of dependence involves estimation of multivariate densities, so that my recent research has included studying the estimation of a functional of a multivariate density.

A separate area of research has been inference for extreme values. This has been motivated by, for example, the problem of determining whether extreme concentrations of pollutants exceed levels that are considered hazardous to health or environment.

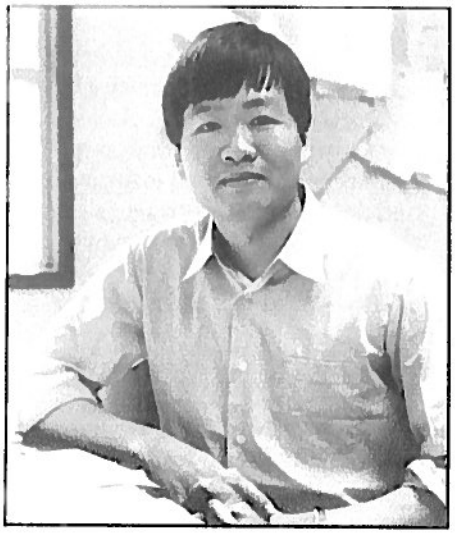
SELECTED PUBLICATIONS

Joe, H. (1985). "An ordering of dependence for contingency tables." *Linear Algebra and its Applications, Special Statistics Issue*, **70**:89-103.

Joe, H. (1987). "An ordering of dependence for distributions of k-tuples, with applications to lotto games." *Canadian Journal of Statistics*, **15**:227-238.

Joe, H. (1987). "Estimation of quantiles of the maximum of N observations." *Biometrika*, **74**:347-354.

Joe, H. (1988). "Relative entropy measures of multivariate dependence." *Journal of the American Statistical Association.*



Jian Liu

ASSISTANT PROFESSOR

B.S. (1982), Zhongshan University

M.S. (1984), Jinan University

Ph.D. (1987), Colorado State University

The University of British Columbia (1987-present)

RESEARCH INTERESTS

I am currently interested in time series analysis, especially in the area of non-classical time series models. Model building and forecasting are my primary concerns.

Data collected sequentially in time can frequently be regarded as a realization of some time series model. A good fit of data may lead to a more accurate forecasting. Classical time series analysis involves finding the best fit among linear parametric models with Gaussian innovations. The mechanism used is the fundamental Wold's decomposition. A systematic account of this subject can be found, for instance, in Brockwell and Davis (1987).

Since data collected in practice often exhibit non-linearity and thus cannot be satisfactorily modelled by a linear time series, new models have been proposed. These models include bilinear time series, threshold models, and the linear model with infinite variance. Applications have been found in economics, business, industry, and the geological sciences. My work in this area includes the theoretical study of existence, efficient estimation, large sample properties, and forecasting. Numerical study via simulation is used from time to time. I am also interested in the applications of the techniques in modelling and forecasting to some practical data sets from our projects.

Another direction of my interests is regression analysis, in particular, variance components models.

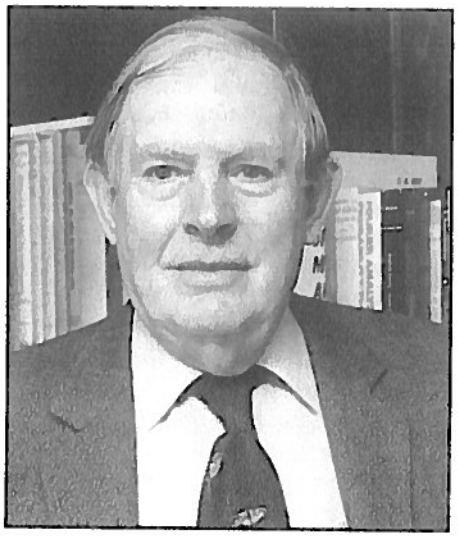
PUBLICATIONS

Liu, J. (1985). "Admissible Estimation for the parameters of linear models." *Mathematical Research and Exposition*.

Liu, J. (1987). "A class of bilinear time series with infinite variance." Technical Report #59, Department of Statistics, The University of British Columbia.

Liu, J. and Brockwell, P.J. (1988). "The general bilinear time series." *Journal of Applied Probability*.

Liu, J. (1988). "A simple condition for the existence of some stationary bilinear time series." Technical Report, Department of Statistics, University of Melbourne.



Stanley W. Nash

PROFESSOR EMERITUS

B.A. (1939), College of Puget Sound

M.A. (1946), University of California, Berkeley

Ph.D. (1950), University of California, Berkeley

Active teaching at UBC (1950-1984)

Visiting Associate Professor, Iowa State University (1960-1961)

President of the Biometric Society, Western North American Region (1966)

Professor Emeritus, The University of British Columbia (1981-present)

RESEARCH INTERESTS

In the past I have worked on various problems in the design of experiments and multivariate analysis. For instance an experiment may test many genetic strains of some plant and find significant differences. If one then compares a few of the strains which did the very best with those that were the very worst in the first experiment, one may occasionally find no significant differences in the second experiment. I did a thorough analytical study of the power functions of the overall tests of differences in the two experiments and showed how and why the seemingly paradoxical outcomes in the two experiments can frequently occur.

Canonical correlation analysis can be used to carry out a discriminant type of analysis. With a new standardization of the canonical variates Mahalanobis distances can be calculated between populations using either of the two sets of (random) variables of canonical correlation analysis. This type of analysis was applied to an extensive provenance study of Sitka spruce in British Columbia and Alaska for which both botanical and geographical sets of variables were available.

Similar analyses can be carried out when one considers the correspondence type of analysis of two-way contingency tables. I have done extensive work on this, but never published my results.

At the present time I am interested in problems dealing with three or more sets of (random) variables, which one wants to deal with in a canonical way to accomplish purposes similar to those dealt with by the canonical correlation analysis of two sets of random variables. There have been a number of models proposed, especially in psychometric literature, but none are entirely satisfactory, particularly when applied to other fields. I would also like to see how such three-mode and higher methods can be adapted to dealing with three-way and higher dimensional contingency tables.

SELECTED PUBLICATIONS

Nash, S. (1954). "An extension of the Borel-Cantelli lemma." *Annals of Mathematical Statistics*, **25**:165-167.

Nash, S. (1956). "Contribution to the theory of experiments with many treatments." *University of California Publications in Statistics*, **2**: No. 8, 167-183. University of California Press.

Nash, S. and Ahuja, J.C. (1967). "The generalized Gompertz-Verhulst family of distributions." *Sankhya, Series A*, **29**:141-156.

Nash, S. and Falkenhagen, E.R. (1978). "Multivariate classification in provenance research: a comparison of two statistical techniques." *Silvae Genetica*, **27**:14-23. Corrections [of misprints], Ibidem, **28**:117.

A. John Petkau

PROFESSOR

B.Sc. (1971), University of Manitoba

Ph.D. (1975), Stanford University

Instructor, Massachusetts Institute of Technology (1974-76)

Visiting Associate Professor, Harvard School of Public Health (1981-82)

SERC Visiting Research Fellow, University of Sussex (1986-87)

The University of British Columbia (1976-present)

RESEARCH INTERESTS

My primary research interest concerns the design of sequential experiments for potential clinical applications. Due to ethical considerations, clinical experiments are inherently sequential and proposed designs should reflect this reality.

Although clinical experiments traditionally have been designed from the hypothesis-testing point of view, the criteria implicit in this approach may not always be the most relevant in clinical settings. An alternate approach combines Bayesian and decision-theoretic aspects and attempts to incorporate considerations of patient benefit. My research has focused on investigating this approach, developing analytical and computational methods to determine optimal designs and evaluate competitors. The results are intended to stimulate consideration of the relevant criteria for designing clinical experiments.

Recent research involves the investigation of the use of group sequential designs. In related work, group sequential procedures have been developed for the interim monitoring of multi-arm clinical trials.

In the treatment of some diseases, a large number of drugs may be available for trial. Typically, a pilot study identifies sufficiently promising treatments to be subjected to more detailed investigation, but little attention has been paid to the design of such pilot studies. Sequential, or multistage, plans are desirable to quickly eliminate ineffective treatments. The problem can be thought of as attempting to make efficient use of a screening facility in the context of a programme of clinical research where new, potentially effective, agents are constantly being produced. A simple model for an idealized situation is being investigated analytically and computationally. The results will provide conclusions concerning how such experiments should be conducted and the efficiency gains provided by sequential experimentation.

Other research is primarily related to two general areas of activity in the Department. One is collaborative research with subject area investigators on such problems as: design and analysis for quantal response experiments, investigation of the index of dispersion in the detection of spatial pattern, statistical considerations in planning cost-of-production studies, analysis in clinical trials for multiple sclerosis, and models for longitudinal ordered categorical data. The second area, environmental and spatial statistics, reflects my participation in a study on statistical methods for obtaining and analyzing acid rain and related data, funded by the Environmental Protection Agency and described in this brochure.

SELECTED PUBLICATIONS

Chernoff, H. and Petkau, A.J. (1981). "Sequential medical trials involving paired data." *Biometrika*, **68**:119-132.

Joe, H., Koziol, J.A. and Petkau, A.J. (1981). "Comparison of procedures for testing the equality of two survival distributions." *Biometrics*, **37**:327-340.

Olkin, I., Petkau, A.J. and Zidek, J.V. (1981). "A comparison of n-estimators for the binomial distribution. "*Journal of the American Statistical Association*, **76**:637-642.

Michelassi, F., Landa, L., Hill, R.D., Lowenstein, E., Watkins, W.D., Petkau, A.J. and Zapol, W.M. (1982). "Leukotriene D4: A potent coronary artery vascoconstrictor associated with impaired vertricular contraction." *Science*, **217**:841-843.

Koziol, J.A. and Petkau, A.J. (1984). "Relative efficiencies of goodness of fit procedures with truncated data." *Canadian Journal of Statistics*, **12**:107-117.

Chernoff, H. and Petkau, A.J. (1986). "Numerical solutions for Bayes sequential decision problems." *SIAM Journal on Scientific and Statistical Computing*, **7**:46-59.

Michael Schulzer

PROFESSOR

B.A. (1958), The University of British Columbia

M.A. (1959), The University of British Columbia

M.D. (1963), The University of British Columbia

Ph.D. (1967), University of Washington

The University of British Columbia (1968-present)

RESEARCH INTERESTS

Since I have both a medical degree and a Ph.D. in Statistics, I act regularly as both a researcher in and consultant to medical research groups as well as teaching regularly in the Statistics Department. I provide specialized short courses of instruction to such groups at the Vancouver General Hospital and at the University of British Columbia Hospital. These courses deal with the design of medical experiments and methodology for analyzing the results.

I am currently a coinvestigator in a Low Tension Glaucoma Study, funded by the Foundation for Glaucoma Research, headquartered in San Francisco. This five year longitudinal study, which began in November of 1986, involves hundreds of patients from more than thirty three centres in North America, Europe, and Japan. The purpose of this collaborative randomized study is to determine the effect of treatment on the progression of this disease.

SELECTED PUBLICATIONS

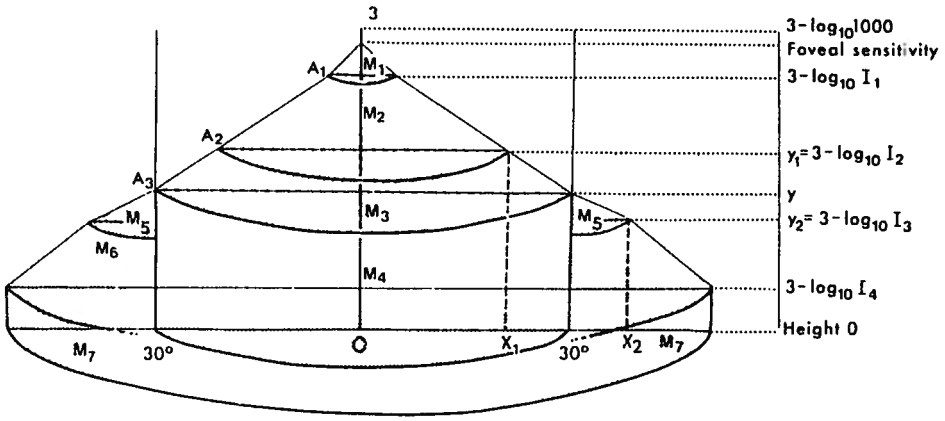
Schulzer, M. (1961). "Asymptotic solutions of integral equations in Banach spaces." *Canadian Journal of Mathematics*, **13**:593-504.

Schulzer, M. (1969). "Contributions to the k-sample problem: a symmetric statistic." *Annals of Mathematical Statistics*, **40**:1933-1949.

Drance, S.M., Schulzer, M., Douglas, G.R. and Sweeney, V.P. (1978). "The use of discriminant analysis in the identification of individuals with glaucomatous visual field defects." *Archives of Opthalmology*, **96**:1571-1573.

Schulzer, M., Chan-Yeung, M. and Tan, F. (1982). "On the possible significance of the quadratic effect of age on lung function measurements." *Canadian Journal of Statistics*, **10**:293-303.

Schulzer, M. and Drance, S.M. (1987). "Intraocular pressure, systemic blood pressure and age: a correlational study." *British Journal of Opthalmology*, **71**:245-249.



The quantification of mass of the visual field.

Ruben Zamar

ASSISTANT PROFESSOR

Degree in Business (1973), University of Cordoba

M.Sc. (1977), CIENES, Chile

M.Sc. (1982), Federal University of Pernambuco, Brazil

Ph.D. (1985), University of Washington

Instructor, Federal University of Pernambuco, Brazil (1974-1976)

The University of British Columbia (1986-present)

RESEARCH INTERESTS

My research interest centres on robust statistics. Robust statistics is concerned with the fact that many assumptions commonly used in statistics (normality, linearity, independence) are at most approximations to reality. Classical parametric statistics (frequentist or Bayesian) derives optimal procedures under exact parametric models. Robust statistics is concerned with the behaviour of statistical procedures when the model assumptions are only approximately valid. There are several approaches to the robustness problem. I am particularly interested in the bias-robustness approach: that is, the study of the distortions caused on the asymptotic behaviour of statistical procedures, mostly point estimates, when arbitrary contamination (possibly non-symmetric) effects the data.

I am also interested in the problem of robust estimation in the Errors-in-Variables (E-V) model. The E-V model assumes that both explanatory and response variables are subject to random observational error. The maximum likelihood procedure under the Gaussian E-V model is the method of orthogonal regression (OR). OR has several attractive practical features, but it is non-robust, as it is very sensitive to some kinds of non-normality of the data. It prompted the search for closely related robust methods, in particular, the adaptation to the orthogonal regression setup of robust methods developed in the classical regression setup: M-estimates, GM-estimates and S-estimates, among them.

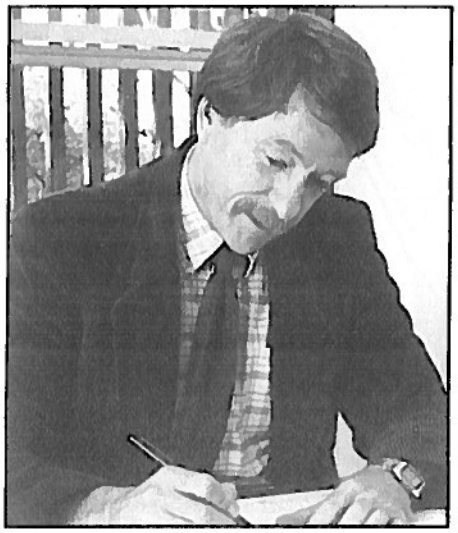
SELECTED PUBLICATIONS

Martin, D.R. and Zamar, R.H. (1987). "Min-max bias robust estimates of scale." Technical Report #72, Department of Statistics, University of Washington.

Zamar, R.H. (1987). "Robust estimation in the errors in variables model." Technical Report #60, Department of Statistics, The University of British Columbia.

Martin, D.R., Yohai, V.J. and Zamar R.H. (1987). "Min-max bias robust regression."

Yohai, V.J. and Zamar, R.H. (1988). "High breakdown point estimates of regression by means of the minimization of an efficient scale." *Journal of the American Statistical Association*. 83:406-413.



James V. Zidek

PROFESSOR

B.Sc. (1961), University of Alberta

M.Sc. (1963), University of Alberta

Ph.D. (1967), Stanford University

Sessional Lecturer, University of Alberta (1962-63)

Honorary Research Fellow, University College London (1971-72)

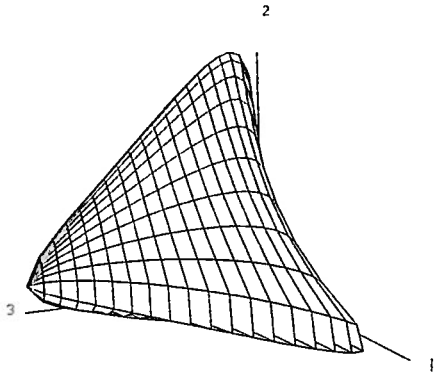
Senior Research Scientist, Commonwealth Scientific and Industrial Research Organization, (1975-76)

The University of British Columbia (1967-present)

RESEARCH INTERESTS

Continuing research in the field of decision analysis has two interconnected aspects. The first is that of combining the opinions of several individuals. These might well be experts, for example, and their opinions may derive from different studies and backgrounds. It is assumed that these opinions are expressed as odds in favour of a proposition like "there will be an earthquake in California tomorrow." The likelihood of such a proposition will differ from expert-to-expert and the problem is how to combine these likelihoods at the end of the day. Various solutions have been developed and under certain assumptions about the attitudes of the individuals, relatively simple formulas obtain. Most of the work to date indicates that a geometric weighted average of the likelihoods is the most appropriate summary.

The other aspect of this problem involves not only the likelihood ordering of the experts, but their preferences as well. The object in this instance is a joint statistical decision on the part of the individuals involved. A decision might for example be "open the resort to skiers tomorrow." Each individual will have likelihoods attached to the possibility of an avalanche, and, in addition, will have values attached to injury, loss of revenue, and loss of life, though these may be implicit. A fairly general statistical theory for the joint estimation of important uncertain quantities has been developed.



Surface representing three statisticians' values of estimates. Each point on the surface corresponds to a particular estimate and its coordinates indicate the three values attributed to the estimator.

Another stream of current research derives from the Acid Rain Research Program in the Department of Statistics supported by the Environmental Protection Agency of the United States under a Cooperative Research Agreement with the Societal Institute for the Mathematical Sciences.

The objective of this study is the development of methods for analyzing trends in acid deposition. The methods look for smooth underlying "signals" in what are generally extremely noisy environmental data.

Also of importance is the derivation of good networks to measure the impact of acid rain and for example, the impact of the closure of a smelter or the adoption of a new pollution abatement technology. Again, the methods produced are quite general and would be applicable in other contexts as well.

SELECTED PUBLICATIONS

Zidek, J. and Hwang, J. (1982). "Limit theorems for out-guesses with mean-guided second guessing." *Journal of Applied Probability,* **9**:209-215.

Zidek, J. and Weerahandi, S. (1983). "Elements of multi-Bayesian decision theory." *Annals of Statistics*, **11**:1032-1046.

Zidek, J. and Rukhin, A.L. (1985). "Estimation of linear parametric functions for several exponential samples." *Statististics and Decision*, **3**:225-238.

Zidek, J. and Genest, C. (1986). "Combining probability distributions: a critique and an annotated bibliography." *Statistical Science,* **1**:114-148.

Zidek, J. and McCullagh, P. (1986). "Regression methods and performance criteria for small-area populations estimation." *Small Area Statistics: An International Symposium* (eds. R. Platek, J.N.K. Rao, C.E. Sarndal, and M.P. Singh), 62-74.

SELECTED MASTERS THESES

EVERETT EDGAR HUNT (1951)
SUPERVISOR: S. Nash
THESIS TITLE: *Non-parametric Two-sample Tests of Statistical Hypotheses.*

YVONNE GERMAIN MARIE GHISLAINE (Nee HENRION) **CUTTLE** (1956)
SUPERVISOR: S. Nash
THESIS TITLE: *The Distribution of the Extreme Mahalanobis Distance from the Mean.*

WILLIAM RIXFORD KNIGHT (1957)
SUPERVISOR: S. Nash
THESIS TITLE: *Some Optimum Properties and Applications of Stein's Test.*

PAUL EMMET LEAVERTON, JR. (1961)
SUPERVISOR: S. Nash
THESIS TITLE: *Estimating the Components of Mixed Logistic Distributions.*

MARGUERITE ELAINE BARRETT (1962)
SUPERVISORS: S. Nash, L. Schwartz
THESIS TITLE: *Stochastic Processes in Population Studies.*

WALTER ERVIN DIEWERT (1964)
SUPERVISOR: S. Nash
THESIS TITLE: *Analysis of Variance Estimators for the Seasonal Adjustment of Economic Time Series.*

GEORGE EDWARD JOHN SMITH (1965)
SUPERVISOR: S. Nash
THESIS TITLE: *Parameter Estimation in Some Multivariate Compound-Distributions.*

VIRGINIA BERYL (nee BERRY) GREEN (1967)
SUPERVISOR: S. Nash
THESIS TITLE: *A Transformation to Stabilize the Variance of Binomial Distributions.*

JOHN TERRY SMITH (1967)
SUPERVISOR: S. Nash
THESIS TITLE: *Fitting Spline Functions by the Method of Least Squares.*

REIMAR HAUSCHILDT (1969)
SUPERVISOR: J.V. Zidek
THESIS TITLE: *Saddlepoint Approximations to Distribution Functions.*

SIOW-LEONG ANG (1970)
SUPERVISOR: S. Nash
THESIS TITLE: *Generalized Matrix Inverses and the Generalized Gauss-Markoff Theorem.*

DICK HUMPHRIES (1971)
SUPERVISOR: J.V. Zidek
THESIS TITLE: *Testing for and Selecting Strong Players in a Tournament.*

LILIAN (nee FEURERVERGER) **MAST** (1973)
SUPERVISOR: S. Nash
THESIS TITLE: *An Analysis of Multidimensional Contingency Tables.*

LAURENCE WO-CHEONG CHEN (1974)
SUPERVISOR: S. Nash
THESIS TITLE: *The Estimation of a Characteristic Function and its Derivatives.*

NANCY M. REID (1976)
SUPERVISOR: J.V. Zidek
THESIS TITLE: *Statistical Analysis of Survival Data: An Application of Coronary By-Pass Surgery.*

DAVID WILSON FYNN (1976)
SUPERVISOR: J.V. Zidek
THESIS TITLE: *Estimating the Intensity Function of the Non-Stationary Poisson Process.*

SANDRA LEE WILSON (1977)
SUPERVISORS: S. Nash, S.J. Press, B.J. Morrison
THESIS TITLE: *A Statistical Classification of Breast Cancer Patients by Degree of Nodal Metastases.*

CHERYL MCKEEMAN (1978)
SUPERVISOR: J.V. Zidek, S. Nash
THESIS TITLE: *Statistical Analysis of Math 100 Grades Related to B.C. High School Factors.*

HARRY SUE WAH JOE (1982)
SUPERVISOR: A.J. Petkau
THESIS TITLE: *Comparison of Procedures For Testing The Equality of Survival Distributions.*

VIVIEN FREUND (1984)
SUPERVISOR: A.J. Petkau
THESIS TITLE: *Survival and Growth Curve Analysis Applied to a Barnacle Data Set.*

EDGAR G. AVELINO (1984)
SUPERVISOR: A.J. Petkau
THESIS TITLE: *The Index of Dispersion.*

PREETHI KOTEGODA (1985)
SUPERVISOR: N. Reid
THESIS TITLE: *Statistical Analysis of Survival Data: An Application to Peripheral Vascular Bypass Surgery.*

BRIAN LEROUX (1985)
SUPERVISORS: P. Greenwood, A.J. Petkau
THESIS TITLE: *Likelihood Ratios in Asymptotic Statistical Theory.*

ABSTRACT: This thesis deals with two topics in asymptotic statistics. A concept of asymptotic optimality for sequential tests of statistical hypotheses is introduced. Sequential Probability Ratio Tests are shown to have asymptotic optimality properties corresponding to their usual optimality properties. Secondly, the asymptotic power of Pearson's chi-square test for goodness of fit is derived in a new way.

The main tool for evaluating asymptotic performance of tests is the likelihood ratio of two hypotheses. In situations examined here the likelihood ratio based on a sample of size n has a limiting distribution as n approaches infinity and the limit is also a likelihood ratio. To calculate limiting values of various performance criteria of statistical tests the calculations can be made using the limiting likelihood ratio.

LINDSAY DUNN (1986)
SUPERVISOR: N. Reid
THESIS TITLE: *Modelling Survival Rates in Bilateral Breast Cancer.*

ABSTRACT: This study involves modelling hazard rates for failure from two related causes, unilateral and bilateral breast cancer in women. Of interest is the incorporation of information from cases who survived the first cause of death into the hazard for the second cause of death.

Proportional hazards regression models and survival plots are used to investigate this question for breast cancer patients seen by the A. Maxwell Evans Clinic in Vancouver; a large data set was provided by the Cancer Control Agency of British Columbia.

It is discovered that controls and cases differ in covariates important to the first cause of death. As a result, hazard functions for the two causes of death are not directly comparable. A multistate model using hazards specific to particular transitions towards death is recommended for further analysis of the survival relationships.

RANDY R. SITTER (1986)
SUPERVISOR: A.J. Petkau
THESIS TITLE: The Design of Quantal Response Experiments and Modelling of Quantal Response Experiments Over Time.

ABSTRACT: Prompted by an enquiry concerning a study intended to provide an economic valuation of the British Columbia tidal sport fishery for the Department of Fisheries and Oceans, Vancouver, the first part of this thesis determines locally optimal designs, as well as more realistic suboptimal but still highly efficient designs, for quantal response experiments; these results provide specific recommendations for the sport fishery study. The second part of the thesis develops models for quantal response experiments where the experimental units are observed repeatedly over time. These models are applied to a data set analyzed by a quite different approach in Carter & Hubert (*Biometrics* 40:699-706, 1984); the results suggest the latter approach is potentially misleading.

D. NHU LE (1986)
SUPERVISOR: A.J. Petkau
THESIS TITLE: *The Statistical Analysis of the Spatial and Tempora-Structure of pH Measurements.*

ABSTRACT: The first part of this thesis provides an attempted validation of the Eynon & Switzer spatial-temporal stochastic model (*Canadian Journal of Statistics* 11:11-24, 1983) for event-based pH measurements resulting from a monitoring network. The results indicate that this model fails to capture some of the features of the underlying structure in the validation data set. The second part of the thesis provides a detailed examination of the validation data set with the goal of developing a useful spatial-temporal structure. The analysis reveals a surprising lack of structure, leaving the view that additional covariate data would be needed to account for the variability of rainfall acidity.

HON WAI MA (1986)
SUPERVISOR: H. Joe
THESIS TITLE: *Smoothing Locally Regular Processes by Bayesian Nonparametric Methods, with Applications to Acid Rain Analysis.*

ABSTRACT: Several nonparametric smoothing methods (kernel, spline, exponential smoothing, robust locally weighted regression) for recovering an unknown smooth function are surveyed and compared with the Bayesian nonparametric approach of Weerahandi and Zidek (1985). For the Weerahandi and Zidek method, cross-validation and "backfitting" are used to estimate the hyperparameters of a prior. Applications to acid rain wet-deposition time series are given.

MAI THOMPSON (1987)
ADVISOR: H. Joe
THESIS TITLE: *Statistical Modelling of Sediment Concentration.*

ABSTRACT: A statistical study and modelling of sediment transport observations are performed. The relationship between stream flow and load of sediments transported in suspension is modelled using appropriate regression/time series, and estimates of long term loads and corresponding standard errors are obtained.

ROBERTO BENCIVENGA (1987)
SUPERVISOR: M. Schulzer
THESIS TITLE: *A Statistical Analysis of Electroencephalographic Spikes in Benign Rolandic Epilepsy of Childhood.*

ABSTRACT: The occurrence of spikes in an electroencephalogram is a basic feature of Benign Rolandic Epilepsy of Childhood (BREC). This thesis studies several aspects of the structure of such spikes. The currently used mathematical model describing the spike assumes that all of the inter-spike variation is due to background activity. However, by studying a slightly richer model, it is shown that non-negligible additional variability is present during the spike. The technique of "spike averaging", presently used to obtain more precise estimates of the signal, is compared with other techniques. This comparison indicates that the current method is an adequate one. Three automated procedures for detecting the exact location of the spike are compared, and it is found that the procedures yield similar location estimates. Finally, characteristics of the spikes of two groups of subjects, who suffer from two different forms of BREC, are compared using Classification and Regression Tree Analysis.

PING H. MA (1987)
SUPERVISOR: F.P. Glick
THESIS TITLE: *Disagreement: Estimation of Relative Bias or Discrepancy Rate.*

ABSTRACT: Not only basic research in sciences, but also medicine, law, and manufacturing need statistical techniques, including graphics, to assess disagreement. If, for instance, each of n items is measured by two distinct methods or by two observers, with D_1...,D_n characterizing the discrepancies in measurement, then disagreement may be characterized by location and scale parameters of the distributions of the D_i's. Discrepancies often violate assumptions of standard statistical models and methods that have been commonly applied in studies of agreement. D_1, D_2,...,D_n may not be identically distributed: perhaps the variance of D_i is proportional to the size of the i-th item.

To estimate median discrepancy, we consider nonparametric confidence intervals corresponding to Student t test, sign test, Wilcoxon signed rank test, or other permutation tests. Several criteria are developed to com-

pare the performances of two procedures, including expected ratio of confidence interval lengths (related to Pitman asymptotic relative efficiency of tests) and relative variability of interval lengths. Theoretical calculations and Monte Carlo simulation results suggest different procedural preferences for random sampling from different distributions. We also emphasize graphic methods, for exploratory analysis of discrepancy data and for appropriate choice of statistical models and numerical methods.

ROBERT LEE (1987)
SUPERVISOR: H. Joe
THESIS TITLE: *A Statistical Analysis of Finding the Best Predictor of Success in First Year Calculus at the University of British Columbia.*

ABSTRACT: A statistical analysis of the relationship between math (calculus) grades for UBC first year students and their Grade 12 high school grade and provincial exam grade is performed. It is of interest to determine which one of the pre-university grades is a better predictor of performance in calculus at UBC. Also of interest is how other factors such as geographical region and participation in the provincial Euclid competition affect the prediction.

SELECTED Ph.D. THESES

OM PARKASH BAGAI (1960)
SUPERVISOR: S. Nash
THESIS TITLE: *Multiple Comparison Methods and Certain Distributions Arising in Multivariate Statistical Analysis.*

JAGDISH CHAND AHUJA (1963)
SUPERVISOR: S. Nash
THESIS TITLE: *Statistical Problems in the Study of Growth.*

ROBERT RICHARD RENNIE (1968)
SUPERVISOR: S. Nash
THESIS TITLE: *Finite Mixtures of Distributions with Common Central Moments.*

JOHN F. BREWSTER (1972)
SUPERVISOR: J.V. Zidek
THESIS TITLE: *On the Admisibility of Scale and Quantile Estimators.*

SAMARADASA WEERAHANDI (1976)
SUPERVISOR: J.V. Zidek
THESIS TITLE: *Bargaining Solutions to the Problem of Exchange of Uncertain Ventures.*

KAM-WAH TSUI (1978)
SUPERVISOR: J.V. Zidek
THESIS TITLE: *Simultaneous Estimation of the Parameters of the Distributions of Independent Poisson Random Variables.*

CHRISTIAN GENEST (1982)
SUPERVISOR: J.V. Zidek
THESIS TITLE: *Towards A Consensus of Opinion.*

ABSTRACT: This thesis addresses the problem of combining the prior opinions, expressed as probability density functions, of a group of individuals. In the first of the two parts of the thesis, various axiomatic systems are developed which characterize successively the linear opinion pool which simply takes a weighted average of the individual prior density functions on the one hand, and the logarithmic opinion pool which takes a geometric average of these densities on the other. The axioms involved are surprisingly weak given the structured form of the resulting opinion pools. Adding an axiom leads to an impossibility theorem showing that essentially, the group must appoint a dictator in order to satisfy the axioms. In the second portion of the thesis it is argued that the domain of pooling operators should be extended beyond densities. The notion of "propensity function" is introduced and examples are given which motivate the generalization. These examples include the well-known problem of combining P-values. Again an axiomatic characterization of a pooling operator is deduced.

ANDREW J. COLDMAN (1987)
SUPERVISOR: A.J. Petkau
THESIS TITLE: *The Development of Resistance To Anticancer Agents.*

ABSTRACT: This thesis explores the mechanism of resistance of tumour cells to chemotherapeutic agents using probabilistic models which assume that resistant cells arise spontaneously with a defined frequency. The resistance process is embedded in a discrete time Markov branching process which models the growth of the tumour and contains three separate cell types: stem, transitional and end cells. Parameters relating to stem cell behaviour determine the asymptotic behaviour of the system and it is argued that, for biologically likely parameter values, cure of the tumour will occur if all stem cells are eliminated.

A model is then developed for the acquisition of resistance by stem cells to a single drug. Probability generating functions are derived which describe the behaviour of the process after an arbitrary sequence of drug treatments. Expressions for the probability of ultimate extinction of the stem cell compartment are derived for a number of experimental situations and the effects of variation in the parameter values are examined. This work is extended to the case where two anticancer drugs are available. The problem of therapeutic scheduling is examined and under situations where drugs are of equal effectiveness but may not be given together, it is shown that the mean number of tumour cells is minimised by sequential alternation of the drugs.

These models are applied to data collected on the L1210 leukemia treated by the drugs Cyclophosphamide and Arabinosylcytosine. In both cases the data provides evidence that resistant cells arise spontaneously with a frequency of approximately 10^{-7} per division. When applied to human breast cancer, the model indicates that neo-adjutant therapy is unlikely to greatly influence the likelihood that the patient will die from the growth of drug-resistant cells.