PROJECT SUMMARY

Name of institution:
Department of Range Science
Colorado State University

Address:
Department of Range Science
Colorado State University
Fort Collins, Colorado 80523

Principal Investigator:
Donald A. Jameson

Title of project:

WORKSHOP ON APPLICATION OF FILTERING, SMOOTHING AND STATISTICAL PREDICTION TECHNIQUES TO LONG TERM ECOLOGICAL DATA

Technical abstract:

Powerful statistical techniques for filtering and smoothing of noisy data in combination with predictive models were developed during the period 1960-1980 for aerospace guidance systems. Recent work at Colorado State University has modified these techniques to short runs of data (10-100 points in time), which make the techniques highly suitable for data collected as part of the Long Term Ecological Research program. Significant improvements in statistical confidence, or a corresponding decrease in sampling cost, can readily result from these procedures. Optimum sampling design for future measurements is a further product. This workshop will train LTER participants in these techniques, and assist participants in preparing data summaries of existing LTER data. A handbook and software for the statistical analyses will be provided to each workshop participant.

PROJECT DESCRIPTION

OBJECTIVES AND SIGNIFICANCE OF THE WORKSHOP

Monitoring of continuing ecological processes has become a common concept in natural resource management and applied ecology. However, in many cases where the term monitoring is used the discussion is restricted to measurement techniques. Monitoring implies a sequence of measurements, and the material presented in this workshop covers statistical monitoring techniques which can significantly aid in sampling efficiency and interpretation of noisy data. For the purposes of this workshop, monitoring will be defined as the repetitive measurement of some state or condition of a system in order to acquire knowledge of the state or condition within a specified limit of error. An optimal monitoring procedure achieves this goal at the lowest possible cost.

Let us suppose that a measurement series consists of just two measurements, one at Time 1 and one at Time 2. Both measurements contain statistical errors. Although the results of the measurement at Time 1 are often tacitly considered to be adequate in the interval between Time 1 and Time 2, it is, unfortunately, common that all of the information from the first measurement is discarded at the time the second measurement is taken. In monitoring, as treated here, the question becomes: at the time of the second measurement is there remaining information from the first measurement that can be used to reduce the statistical error at Time 2? By determining the amount of useful information remaining from previous measurements, the information quality can be improved (which is equivalent to saying that the total measurement cost can be reduced). As a result of improved statistical quality, the effect of random noises can be reduced and more meaningful interpretation of data can result.

Reduction in measurement cost to achieve a given statistical error is the major emphasis in monitoring, and the subject is generally treated under the title of "optimal estimation" in the engineering literature. However, applications in natural resource management and ecology, and the mathematical background of practitioners in these fields, require a different treatment than in engineering.

As a contribution to increased scientific production of the LTER program, each participant will be asked to bring an appropriate data set from his/her own investigations. Statistical analyses of these data will be completed during the workshop.

PARTICIPANT SELECTION PROCESS

Priority for attendance at the workshop will be given to LTER personnel who are responsible for data management at their appropriate sites. Each participant will bring appropriate data for analysis during the workshop: appropriate data should include at least (1) estimates (measurements) of the state of the ecological system for ten or more points in time, (2) an estimate of the sampling error which occurs when multiple measurements are made a single point in time, and (3) at least a rudimentary model which is capable of making projections from one point in time until the next point in time.

Mathematical background for the workshop is minimal. Almost no knowledge of calculus is required; a simple derivative is used only once, and no serious harm will be done if the participant does not understand the procedure of finding a derivative. A knowledge of elementary statistics is required, including the definitions of mean, standard deviation, standard error of the mean and variance. Knowledge of simple correlation and regression analysis is also helpful. The computations are simple enough that they can be done by hand, but they are recursive and the ability to use spreadsheets on a personal computer or a programmable calculator would reduce the tedium.

Worksheets suitable for LOTUS and many other spreadsheets will be provided for numerical examples of the key points of the workshop. For those not familiar with LOTUS, most of the techniques will also be available in complied BASIC programs. Each of the worksheets will be studied as part of problem assignments. Time spent with the worksheets will be rewarded with increased understanding of the subject matter and ability to conduct further analyses following the workshop.

WORKSHOP SCHEDULE

I. Get acquainted session. January 10 - (Sunday evening prior to first full days workshop).

II. Problems, definitions, examples, and state-of-the-art in monitoring of long term ecological data. January 11-15 (Monday a.m. through Friday noon). Assembled training sessions will be held from 8:00 a.m. to 9:30 a.m. and 1:10 p.m. to 2:30 p.m. daily, with individual tutoring and work sessions during the remainder of the day.

BIBLIOGRAPHY

The following citations include the current references which make application of Bayesian statistics or filtering techniques to ecological data, and many of the classical background papers which eventually resulted in the availability of these techniques.

Anderson, B. D. O., and J. B. Moore. 1979. Optimal filtering. Prentice-Hall. 357 pp.

Battin, R. H. 1964. Astronautical guidance. McGraw Hill. 400 pp.

Box, G. E. P. and G. M. Jenkins. 1976. Time series analysis: forecasting and control. Holden-Day. 575 pp.

Brewer, J. W. and S. F. Moore. 1974. Monitoring: an environmental state estimation problem. J. Dynamic Systems, Measurement, and Control 96:363-365.

Bryson, A. E., and L. J. Henrickson. 1968. Estimation using sampled data containing sequentially correlated noise. J. Spacecraft and Rockets 5:662-665.

Carande, V., and D. A. Jameson. 1986. Combination of weight estimates with clipped sample data. J. Range Manage. 39:88-89.

Chatfield, C. 1982. The analysis of time series. Chapman and Hall. pp 40-52, 74-75.

Chin, L. 1979. Advances in adaptive filtering. In Control and Dynamic Systems, C. T. Leondes, ed. 15:277-350.

Czaplewski, R. L. 1986. Acceptability of the Kalman filter to monitor pronghorn population size. PhD Dissertation, Colorado State University, Fort Collins.

Dixon, B. L., and R. E. Howitt. 1979. Continuous forest inventory using a linear filter. Forest Science 25:675-689.

Emara - Shabaik, H. E., and C. T. Leondes. 1981. Non-linear filtering -- the link between Kalman an extended filters. Internat. J. Control 34:1207-1214.

Gauss, C. F. 1821. (Collected works 1880) Theoria combinationis observationum erroribus minimis obnoxiase. Werke 4. Göttingen.

Gelb, A. 1974. Applied optimal estimation. MIT Press.

Granger, C. W. J., with M. Hatanaka. 1964. Spectral analysis of economic time series. Princeton Univ. Press. 299 pp.

Harrison, P. J. and C. F. Stevens. 1976. Bayesian forecasting. J. Royal Statistical Soc. Series B 32:205-247.

Hoff, John. 1983. A practical guide to Box - Jenkins forecasting. Lifetime Learning Publ., Belmont, CA.

Jameson, D. A. 1985. A priori analysis of allowable interval between measurements as a test of model validity. Appl. Math. and Computation 17:93-105.

Jameson, D. A. 1986a. Models vs measurements in grazing systems analysis. Proceedings of Society for Range Management Special Symposium, Feb. 1986, Kissimee, FL.

Jameson, D. A. 1986b. Sampling intensity for monitoring of environmental systems. Appl. Math. and Computation 18:71-75.

Jameson, D. A. and E. T. Bartlett. 1987. Selection of optimal management strategies based on stochastic dynamic ecological models. Ecological Modelling 36:5-13.

Jazwinski, A. H. 1970. Stochastic processes and filtering theory. Academic Press. Pages 269-272.

Joseph, P. D., and J. T. Tou. 1961. On linear control theory. Transactions AIEE (Applications and Industry) 80:193-196.

Kailath, T. 1974. A view of three decades of linear filtering theory. IEEE Tr. on Information Theory IT-20:146-181.

Kalman, R. E. 1960. A new approach to linear filtering and prediction problems. J. Basic Engr. (Ser. D) 82:35-45.

Kalman, R. E., and R. S. Bucy. 1961. New results in linear filtering and prediction theory. J. Basic Engr. (Ser. D) 83:95-108.

NSF budget form

COLORADO STATE UNIVERSITY YELLOW SHEET

	OPTION A	OPTION B
SALARIES SUBJECT TO FRINGE		
Faculty/Professional	6248	
Staff/Other	2000	
Subtotal	8248	
Fringe	1551	
SALARIES NOT SUBJECT TO FRINGE		
Student Hourly	500	
TOTAL PERSONNEL	10299	
TRAVEL-Domestic	300	
MATERIALS & SUPPLIES	500	
*LAB/SERVICE CENTERS	2500	
*PRINTING/PUBLICATIONS	900	
*SOFTWARE FOR BASIC-LOTUS CONVERSION	500	
TOTAL OTHER DIRECT	3900	
TOTAL DIRECT	14999	
INDIRECT COSTS		
TOTAL BUDGET		

BUDGET NOTES

Option A.
Participant expenses will be covered by individual LTER projects.

Option B.
Participant expenses will be covered by the workshop project. Additions to the project will be about $850 per participant for room, board and airfare (no indirect cost charged on participant support).

HOUSING AND MEAL ARRANGEMENTS

The workshop will be held at the Colorado State University, campus. Meals will be about $16 per person per day. Housing will be at local motels at $35 per person per day.

COMPUTER FACILITIES

Computer facitities will be provided by the microcomputer facility of the CSU College of Forestry and Natural Resources. Twenty-five IBM compatible work stations connected with a Novell network are available in the CFNR lab. Charges for this facility are $500 per day.

Kolomogroff, A. 1939. Sur l'interpolation et extrapolation des suites stationnaires. Comptes Rendus Hebdomadaires des Séances de L'Académie de Sciences 208:2043-2045.

Maybeck, P. S. 1979. Stochastic models, estimation, and control. Vol.1. Academic Press.

Meier, L. III, J. Peschon and R. M. Dressler. 1967. Optimal control of measurement subsystems. IEEE Transactions on Automatic Control AC-12:528-536.

Naylor, T. H., J. L. Balintfy, D. S. Burdick, and K. Chu. Computer simulation techniques. John Wiley. pp 68-122.

Pimental, K. D. 1975. Toward a mathematical theory of environmental monitoring: the infrequent sampling problem. National Technical Information Service UCRL-51837.

Plackett, R. L. 1950. Some theorems in least squares. Biometrika 37:149-157.

Ryan, T. A. Jr., B. L. Joiner and B. F. Ryan. 1980. Minitab reference manual. 138 pp.

Sisler, J. F. and D. A. Jameson. 1983. Optimal multi-observation monitoring systems, a practical approach. In: Analysis of ecological systems: state of the art in ecological modeling, W. K. Lauenroth, G. V. Skogerboe and M. Flug, eds. Elsevier. pp 235-240.

Soeda, T., and T. Yoshimura. 1973. A practical filter for systems with unknown parameters. J. Dynamic Systems, Measurements and Control 95:396-401.

Sorenson, H. W. 1970. Least-squares estimation: From Gauss to Kalman. IEEE Spectrum 7(July):63-68.

Sorenson, H. W. 1985. Kalman filtering: theory and application. IEEE Press Selected Reprint Series.

Wiener, N. 1949. Extrapolation, interpolation, and smoothing of stationary time series. Wiley. 163 pp.

CURRENT AND PENDING SUPPORT

Current support:
Donald A. Jameson. Supporting agency: Colorado Agricultural Experiment Station. Project title: Herb-herbivore interactions on semiarid steppe. Period covered by support: 1985-89. Person-months per year: 2. Location: Larimer County, Colorado.

POST-PERFORMANCE EVALUATION OF NSF AWARDS

The principal investigator coordinated an NSF funded workshop during September 1986 on the application of supercomputers to landscape dynamics. Sixty individuals attended the workshop, and the proceedings are pending publication in Applied Mathematics and Computation.