THE INSTITUTE OF MANAGEMENT SCIENCES

NEWSLETTER OF THE

TIMS COLLEGE on SIMULATION AND GAMING

LEE SCHRUBEN and W. DAVID KELTON, CO-EDITORS

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*Cast your vote and return mail ballots as indicated on page 9

COLLEGE ON SIMULATION AND GAMING
THE INSTITUTE OF MANAGEMENT SCIENCES
146 WESTMINSTER STREET
PROVIDENCE, RI 02903

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CHAIRMAN'S MESSAGE

As chairman of the TIMS College on Simulation and Gaming, I would like to encourage more of our 250-300 members to take an active role in the activities of the College. The College sponsors a variety of simulation sessions at the ORSA-TIMS meetings and also at the Winter Simulation Conference. Our free cocktail parties at the ORSA-TIMS Meetings have been a good opportunity for people with different backgrounds and interests to interchange ideas. People with ideas for future directions for the College or with general information which may be of interest to the simulation community should write the Newsletter Editor, Lee Schruben.

Averill M. Law, Chairman
TIMS College on Simulation
and Gaming

EDITORIAL POLICY FOR SIMULATION DEPARTMENT

The Simulation Department of *Management Science* is interested in receiving papers in simulation that describe:

a. Innovative ideas for modeling flow (state change) logic in simulated systems.

b. New probabilistic representations of underlying stochastic structures.

c. New and improved methodologies for analyzing simulation output and increasing statistical efficiency in estimation.

d. Unusual applications using existing or new methodological procedures.

In addition to a clear and concise account of a newly proposed technique in topics a, b and c, a paper should describe the merits of the technique relative to currently employed techniques, if such exist, and should include revealing comparisons.

Appropriate subjects under topic a include modeling formulations that are alternatives to the well-established event-scheduling and process-interaction methods. Also appropriate are comparisons of the relative success with which established and, possibly, newly proposed techniques perform computationally for different classes of simulation problems. Such a comparison ordinarily would cover discussions of ease of conceptualization, ease of implementation, language adaptability and computational efficiency.

Topic b is aimed at making available to readers new probabilistic conceptualizations for simulating processes with special characteristics for which an established literature does not now exist. For example, there are at present no standard procedures for generating interarrival times in a queueing simulation that have a particular marginal distribution and are *dependent.* In order to provide useful guidance to readers in resolving such problems, papers under topic b should, in addition to a technical description, include a description of the steps required to implement the concept, together with computation time assessments, as appropriate. The Department is not interested in papers that deal *exclusively* with sampling from standard distributions.

Papers under topic c should describe how the proposed technique compares with past proposals for solving a particular statistical or decision making problem. Here comparison would include considerations of statistical performance, degree of generality, computational efficiency, ease of implementation and simplicity of concept. A methodological paper is expected to demonstrate its proposed technique and evaluate its performance relative to competing techniques. This demonstration should be accomplished with simulation models for which theoretical solutions are known. In this way a reader can assess both absolute and relative performance. In cases in which a paper presents a new methodology in an area where no alternatives exist, the absolute standard will provide the basis for an evaluation. A description of the testing procedure should specify an experimental design for each theoretical model considered. For example, if one is using a queueing model as the basis for testing, one would expect that studying the performance of the proposed technique for a range of traffic intensities would be one element of the experimental design.

The Simulation Department is also interested in publishing papers that describe the successful use of simulation experimentation as an aid in decision making (topic d). A paper in this area should provide a clear, concise account of the simulation to a degree of detail that allows a reader, mildly familiar with the proble, to comprehend the structure and purpose of the simulation model and the related statistical analyses performed on input and output data. A key feature of a paper in this area should be an account of the way in which knowledge gained from simulation experimentation came to influence policy with regard to solving the problem at hand. Here a description of the successful interaction between modelers and decision makers would be regarded as an essential component of the paper.

CONFERENCE ANNOUNCEMENTS

Conference on Computer Simulation: A Research Focus (May, 1982)

Contact:

Professor N. R. Adam	Professor R. E. Nance	Professor R. G. Sargent
Rutgers University	Virginia Polytechnic Institute & State University	Syracuse University

Cosponsors:

Operations Research Society of America, SICSIM of the New York Chapter of ACM Business Research Center, Rutgers Univeristy.

Fourteen invited papers presented during a two-day conference. Each paper is alloted 30 minutes for presentation, followed by a ten minute question and discussion period. The question and discussion period will be taped and edited for subsequent publication.

The following are among the conference participants: R. Andrews, G. Fishman, W. Franta, P. Heidelberger, J. Henriksen, P. Lewis, H. Markowitz, R. Sargent, B. Schmeiser, L. Schruben, T. Schriber, P. Welch, B. Zeigler.

10th IMACS Meeting (Montreal, August, 1982)

A session on Discrete Simulation-Statistical Methods in Simulation is being chaired by Bruce Schmeiser. Speakers in this session are:

1. "Variate Generation: The Current State"
   Dr. Luc Devroye, McGill University.
2. "Output Analysis: The Current State"
   Dr. Phillip Heidelberger, IBM Watson Labs.
3. "Initialization: The Current State"
   Dr. Lee Schruben, Cornell University.
4. "Variance Reduction: the Current State"
   Dr. James R. Wilson, Texas University.
5. "Validation: The Current State"
   Dr. Robert G. Sargent, Syracuse University.

16th Annual Simulation Symposium (Tampa, March, 1983)

Contact: ANNUAL SIMULATION SYMPOSIUM
P. O. Box 22621
Tampa, Florida 33622

Winter Simulation Conference (San Diego, December, 1982)

Contact:

General Chairman	*Program Chairman*	*Associate Program Chairman*
Yen W. Chao	Orlando Madrigal	Bruce Schmeiser
FEDSIM/MV	Computer Science Department	School of Industrial Engineering
U. S. Air Force	California State University	Purdue University
Washington, D.C. 20330	Chico, California 95929	West Lafayette, Indiana 47907
(202) 274-8015	(916) 895-6442	(317) 494-5422

IASTED International Symposium (San Diego, July, 1982)

Contact:

For submission of abstracts: Dr. John Brewer, Department of Mechanical Engineering, The University of California, Davis, CA 95616, U.S.A. (916) 752-1779.

For correspondence and to be placed on the mailing list: The Secretary, ASM '82, P.O. Box 2481, Anaheim, CA 92804, U.S.A.

NATO Advanced Study Institute: Simulation and Model-Based Methodologies: An Integrative View (Ottawa, July-Aug., 1982)

Contact:
Dr. Tuncer Oren
Computer Science Dept.
University of Ottawa
Ottawa, Ontario
Canada K1N9B4

MINUTES OF RECENT COLLEGE MEETINGS

Tuesday, October 13, 1981. 5:30 PM.
ORSA/TIMS Joint National Meeting, Houston.

Attending: John Carson, George Fishman, David Kelton, Averill Law, Chairman, Phil Moser, Bruce Schmeiser, Lee Schruben, Dennis Smith.

George Fishman reported on the status of the Simulation Department of *Management Science*. Several papers are forthcoming.

Averill Law, in the absence of Dick Nance, briefly discussed the Computational Structures and Techniques area of *Operations Research*.

Bruce Schmeiser suggested that we consider becoming an ORSA Special Interest Group (SIG) while jointly remaining a TIMS College. The Applied Probability Group currently has this joint status. The advantage would be to attract those members of ORSA who are not members of TIMS and are interested in simulation. The disadvantage is that the organization would then be subject to two sets of national organization rules. The consensus was that the idea was worth pursuing.

George Fishman suggested we determine the composition of our membership. Lee Schruben said that he and David Kelton, as the Newsletter coeditors, already had begun work on such a project.

Bruce Schmeiser, passing along a comment of Alan Pritsker, mentioned that the College may want to consider being a cosponsor of the summer Simulation Conference. The consensus was that we would gain little by spreading our efforts to the summer meeting, especially since most of our interests are in discrete event simulation and the summer meeting stresses continuous deterministic simulation.

Adjourned: 6:30 PM.

Bruce Schmeiser
Secretary

MINUTES TIMS/CSG MEETING IN ATLANTA

December 10, 1981
Winter Simulation Conference, Atlanta

Attending: Richard Andrews, Bill Biles (presiding), John Carson, Jack Davis, David Kelton, Alan Pritsker, Jim Pruett, Bob Sargent, Bruce Schmeiser, Bill Schmidt, Lee Schruben, Andy Seila, Bob Shannon, Pandu Tadikamalla, Chuck White, and Jim Wilson.

1. Bill Biles called the meeting to order a 5:30 PM.
2. Bruce Schmeiser reviewed briefly the college's award for the best paper in *Management Science*.
3. Lee Schruben and David Kelton discussed the college's newsletter. They encouraged submissions of all types of information.
4. Sessions organized by the TIMS/CSG were reviewed briefly by Bob Sargent and Bill Biles.

5. Seeking joint affiliation with ORSA was discussed. The discussion was a continuation from the meeting in Houston, as reported in the previous minutes. Since the last meeting, Bruce Schmeiser had spoken with Narayan Bhat and Ralph Disney, both of whom felt that the joint affiliation had worked well for the Applied Probability group. Lee Schruben had spoken with George Nemhauser, the current president of ORSA, who in turn had Judy Leibman, the chairman of the Technical Sections Committe of ORSA, send to Bruce Schmeiser information concerning forming a Special Interest Group and/or a technical section.

   Several disadvantages to joint affiliation came to light. First, it is clear that ORSA keeps tighter control over special interest groups and technical sections than TIMS does for its colleges. Thus, the college may be prevented from participating in some activities due to having to satisfy additional rules. A second problem, noted by Bob Sargent, is that the college has a significant amount of money in its treasury and that it may be difficult to find an equitable method for dealing with this potential windfall to ORSA. A third, issue, mentioned by Alan Pritsker, is that ORSA is considering dropping its sponsorship of the Winter Simulation Conference. Alan favored not seeking joint affiliation. He suggested that if it were important for there to be an ORSA special interest group in simulation that it be formed independently.

   The only advantage, and the original motivation, of joint affiliation is that the existing organization would then impact more people. Bob Shannon, after asking those present to indicate whether they were joint ORSA/TIMS members or only TIMS members and finding only about twenty percent of those present to be TIMS only members, noted that the additional impact may not be great.

   Bill Biles suggested asking the membership of the TIMS/CSG (via the newsletter) and potential members now only members of ORSA (via *OR/MS Today)* for their comments. The issue will be on the agenda of the colleges meeting at the spring TIMS/ORSA meeting in Detroit.
6. The meeting adjourned about 6:10 PM.

Bruce Schmeiser
Secretary/Treasurer

SHORT COURSES IN SIMULATION LANAGUAGES

SLAM II

Offered several times per year by Pritsker an Associates, Inc., Box 2413, West Lafayette, IN. 47906 (317-463-5557). A four day comprehensive course on the SLAM II simulation language.

Course Outline:

Day 1: Simulation methodology and modeling perspectives. Network modeling with SLAM II.

Day 2: Discrete event simulation using SLAM II. SLAM II inputs and outputs.

Day 3: Combined network-discrete event modeling with SLAM II. Continuous models.

Day 4: Combined network-discrete event-continuous modeling with SLAM II. Applications of simulation.

SIMULATION WITH GPSS

An intensive five-day course on "Simulation Using GPSS" will be offered in The University of Michigan's Engineering Summer Conferences July 12-16, 1982. The course consists of lectures from 8:30 a.m. until 4:30 p.m. each day, and hands-on experience with GPSS in computing center workshops which take place from 5 p.m. until 8 p.m. on the first, second, and fourth course days. In addition, about 25 hours of directed private study is required before the course begins. For further information, request a course brochure from Prof. Thomas J. Schriber, Graduate School of Business, The University of Michigan, Ann Arbor, MI 48109 (313-764-1398).

Professor Schriber's course will also be offered in the Washington, D.C., area in May, 1982; November, 1982; and January, 1983, under the sponsorship of Wolverine Software Corporation. Particulars for the Washington offerings can be obtained from James O. Henriksen, Wolverine Software Corporation, 7630 Little River Turnpike, Annadale VA 22003 (703-750-3910).

Suite 205

ABSTRACTS OF PAPERS

VALIDATION OF MULTIVARIATE RESPONSE SIMULATION MODELS BY USING HOTELLING'S TWO-SAMPLE T-SQUARE TEST, Osman Balci, Industrial Engineering, Virginia Polytechnic Institute, Blacksburg, VA and Robert Sargent, Industrial Engineering, Syracuse Univ., Syracuse, NY.

A procedure is developed by using Hotelling's two-sample T^2 test to test the validity of a multivariate response simulation model that represents an observable system. The validity of the simulation model is tested with respect to the mean behavior under a given experimental frame.

A trade-off analysis can be performed and judgement decisions can be made as to what data collection budget to allocate, what data collection method to use, how many observations to collect on each of the model and system response variables, and what model builder's risk to choose for testing the validity under a satisfactory model user's risk.

The procedure for validation is illustrated for a simulation model that represents an M/M/1 queueing system with two performance measures of interest.

ANALYSIS OF SPACE SHUTTLE GROUND OPERATIONS James R. Wilson, Mech. Engr., Univ. of Texas, Austin TX, David K. Vaughan, Mech. Engr., Univ. of Texas, Austin TX, Edward Naylor, Arthur Andersen, Houston, TX and Robert G. Voss, Johnson Space Ctr., NASA, Houston TX.

To assess the feasibility of proposed launch schedules for operational flights of the Space Shuttle, a simulation model has been developed for the flow of activities comprising Shuttle turnaround processing. Taking into account queueing delays due to the limited capacity of ground processing facilities, the model estimates flight starting dates which are required to meet a given launch schedule with a specified level of confidence. The results of an extensive sensitivity analysis based on the model indicate that the currently projected flight schedules are too optimistic and that the long-range ground turnaround time for an orbiter will substantially exceed the current goal of 28 days.

ANTITHETIC SAMPLING USING MULTIVARIATE INPUTS, James R. Wilson, Mechanical Engineering, Univ. of Texas, Austin, TX.

This paper extends the antithetic-variates theorem to include the case of two or more random variables, each of which is generated by a sampling scheme requiring a fixed-dimension input vector of independent random numbers.

Key words. Monte Carlo methods, simulation, efficiency, variance-reduction techniques, antithetic variates.

FACTOR SCREENING IN COMPUTER SIMULATION (in *Simulation*, Feb 1982) Dennis E. Smith and Carl A. Mauro, *Desmatics, Inc.*, State College, Pennsylvania 16801.

In many simulation models, only a few input variables have a significant effect on the output. By identifying those variables in some reasonable way, we could undoubtedly make the model simpler, more efficient, cheaper to run, and easier to analyze. Factor screening methods attempt to identify the more important variables. The most effective methods, however, require more computer runs than are normally reasonable or affordable. Thus screening must usually be based on nonstandard designs not customarily discussed in standard statistical references.

In this paper, we review and discuss the major classes of factor screening designs. We pay particular attention to two strategies that are useful when there are more factors than available runs. The first of these is group-screening, in which factors are grouped and tested in a multistage procedure; the other is based on a combination of random balance and Plackett-Burman designs. Unfortunately, the performance of a screening strategy is difficult to measure; the modeler must consider both how much it costs and how accurately it classifies factors. An artificial example illustrates the tradeoffs that the modeler must take.

ON WAITING TIMES FOR A QUEUE IN WHICH CUSTOMERS REQUIRE SIMULTANEOUS SERVICE FROM A RANDOM OF SERVERS, Andrew F. Seila, University of Georgia.

We consider a queueing system, first introduced by L. Green in 1980, in which customers from a Poisson arrival stream request simultaneous service from a random number of identical servers with exponential service times. An expression is given for the Laplace-Stieltjes transform of the stationary distribution of waiting time which corrects the expression given in the original paper. Computational formulas for the mean waiting times and mean waiting times for customers requesting exactly j servers are also given, along with tables of these values for selected systems.

QUANTILE ESTIMATION IN DEPENDENT SEQUENCES, P. Heidelberger, IBM Research Center, Yorktown Heights, NY 10598 and P. A. W. Lewis, Naval Postgraduate School, Monterey, CA 93940.

Standard nonparametric estimators of quantiles based on order statistics can be used not only when the data are i.i.d., but also when the data are from a stationary, ϕ-mixing process of continuous random variables. However, when the random variables are highly positively correlated, sample sizes needed for acceptable precision in estimates of extreme quantiles are computationally unmanageable. A practical scheme is given, based on a maximum transformation in a two-way layout of the data, which reduces the sample size sufficiently to allow an experimenter to obtain a point estimate of an extreme quantile. Three schemes are then given which lead to confidence interval estimates for the quantile. One uses a spectral analysis of the reduced sample. The other two, averaged group quantiles and nested group quantiles, are extensions of the method of batched means to quantile estimation. None of the schemes requires that the process being simulated is regenerative.

AN APPROACH TO REGENERATIVE SIMULATION ON A GENERAL STATE SPACE, Peter Glynn, Univ. of Wisconsin, Madison.

A wide variety of stochastic systems may be viewed as Markov chains taking on values in a general state space. An example is the class of generalized semi-Markov processes, which are commonly obtained in network queueing problems via the technique of supplementary variables. A simulator is often interested in obtaining steady state properties of such a system. Some recent developments in Markov chain theory by Athreya, Ney, and Nummelin allow one to embed a certain subclass of these processes in a regenerative environment. We study some consequences of this embedding and develop statistical estimation procedures for the general problem that bear close resemblance to the regenerative method of simulation analysis for finite state Markov chains.

DESIGN OF EXPERIMENTS IN COMPUTER PERFORMANCE EVALUATION, Martin Schatzoff, in *IBM Journal of Research and Development, Vol. 25, no. 6.*

Techniques of statistical design of experiments have been successfully employed for many decades in a variety of applications in industry, agriculture, medicine, psychology, and other physical and social sciences. Their aim is to provide scientific and efficient means of studying the effects, on one or more variables of interest, of varying multiple controllable factors in an experiment. These technqiues have not been widely used in the study of computer systems, although they can potentially have as large an impact as they have had in other fields. The purpose of this paper is to review some of the basic concepts underlying the statistical design and analysis of experiments and to illustrate them by means of examples drawn from studies of computer system performance. The examples include comparisons of alternate page replacement and free storage management algorithms, optimization of a scheduler, and validation of a system simulation model.

ACCELERATED CONVERGENCE IN THE SIMULATION OF COUNTABLY INFINITE STATE MARKOV CHAINS, George S. Fishman, Curr. of O.R., Univ. of N. Carolina, Chapel Hill, NC.

This paper describes a method of obtaining results from the simulation of a countably infinite state positive recurrent aperiodic Markov chain at a cost considerably below the cost required to acheive the same accuracy with pure random sampling. By reorganizing k independent epochs or tours simulated serially into k replications simulated in parallel, one can induce selected joint distributions across replications that produce the cost-saving benefits. The joint distributions follow from the use of rotation sampling, a special case of the antithetic variate method. The chains considered are of the band type so that for the state space S = (0,1,2,...) there exists an integer σ such that transition from a state i can move no further than to states $i - \sigma$ and $i + \sigma$.

The paper shows that an estimator of interest has variance bounded above by $O(\sigma^2(\ln\#k)^4/k^2)$ when using rotation sampling, as compared to a variance O(1/k) for independent sampling. Moreover, the mean cost of simulation based on rotation sampling has an upper bound $O((\sigma \ln k)^2)$ as compared to at least O(k) for independent sampling.

The paper also describes how one can exploit special structure in a model together with rotation sampling to improve the bound on variance for essentially the same mean cost.

KEYWORDS: Markov chains; rotation sampling; simulation; variance-reduction.

HOW TO CHEAT A MONTE CARLO ESTIMATION OF A SYSTEM'S RELIABILITY, Carl Diegert and Kathleen V. Diegert, Sandia Natl. Labs, Albuquerque, NM.

Computing the probability of system failure can require a great deal of work. In fact, this problem is among the class of problems that computer scientists call the nondeterministic polynomial (NP) complete class. No algorithm is known to solve any of these problems using an amount of computer time bounded by a polynomial function of the size of the network. Since much effort has been spent trying to find such an algorithm, and none has been found, alternatives to direct solutions have also been studied. One alternative is to find bounds to the exact system reliability, which can be computed in polynomial time. Another alternative is to estimate the exact reliability using Monte Carlo techniques (computer simulation). We pursue the Monte Carlo estimation approach, giving a method that may be used for probabilistic networks with unequal component reliabilities.

STRATIFIED ESTIMATION IN REGENERATIVE SIMULATIONS, Andrew F. Seila, Graduate School of Business, Univ of Georgia, Athens, GA.

A method of presented for estimating stationary mean performance measures in regenerative simulation of systems which are stratified, i.e., systems in which every observation can be classified into one of $s > 1$ mutually exclusive categories (strata). A multivariate estimator for within-stratum means is presented and shown to be asymptotically normal. An estimator for the overall mean, which is a linear combination of the within-stratum estimators, is given. This estimator is asymptotically normal and empirical studies show it to have smaller variance for the systems simulated than the usual regenerative estimator, with no decrease in coverage probability.

A VARIANCE REDUCTION STRATEGY FOR RSM SIMULATION STUDIES, Belva J. Cooley, Univ. of Montana and Ernest C. Houck, Virginia Polytechnic Institute, Blacksburg, VA (to appear in *Decision Sciences).*

The application of optimization techniques in digital simulation experiments is frequently complicated by the presence of large experimental error variances. Two of the more widely accepted design strategies for the resolution of this problem include: (1) the assignment of common pseudo-random number streams to the experimental points; and (2) the use of antithetic variates. When considered separately, however, each of these variance reduction procedures has rather restrictive limitations. This paper examines the simultaneous use of these two techniques as a variance reduction strategy in the response surface methodology (RSM) analysis of simulation models. A simulation of an inventory system is used to illustrate the application and benefits of this assignment procedure, as well as the basic components of an RSM analysis.

POISSON RANDOM VARIATE GENERATION, Bruce Schmeiser and Voratas Kachitvichyanukul, School of I. E., Purdue Univ, West Lafayette, IN.

Approximate algorithms have long been the only available methods for generating Poisson random variates when the mean is large. A new algorithm is developed that is exact, has execution time insensitive to the value of the mean, and is valid whenever the mean is greater than ten. This algorithm is compared to the three other algorithms which have been developed recently for generating Poisson variates when the mean is large. Criteria used are set-up time, marginal execution time, memory requirements, and lines of code. New simple tight bounds on Poisson probabilities contribute to the speed of the algorithm, but are useful in a general context. In addition, Poisson variate generation is surveyed.

SAMPLING FROM A DISCRETE DISTRIBUTION WHILE PRESERVING MONOTONICITY, George S. Fishman and Louis R. Moore, III, Curr. of Operation Research , Univ. of North Carolina, Chapel Hill, NC.

This paper describes a cutpoint method for sampling from an n-point discrete distribution that preserves the monotone relationship between a uniform deviate and the random variate it generates. This property is useful when developing a sampling plan to reduce variance in a Monte Carlo or simulation study. The alias sampling method generally lacks this property and requires 2n storage locations while the proposed cutpoint sampling method requires m+n storage locations, where m denotes the number of cutpoints. The expected number of comparisons with this method is derived and shown to be bounded above by $(m + n - 1)/n$. The paper describes an algorithm to implement the proposed method as well as two modifications for cases in which n is large and possibly infinite.

AN ALTERNATIVE VARIANCE REDUCTION STRATEGY FOR RMS SIMULATION STUDIES M. Hossein Safizadeh, Wichita State Univ., Wichita, KS and Billy M. Thornton, Colorado State Univ., Ft. Colins, CO (to appear in *Decision Sciences).*

Cooley and Houck [1] examined the simultaneous use of common and antithetic random number streams as a variance reduction strategy for simulation studies employing response surface methodology (RSM). Our paper supplements their work and further explores pseudorandom number assignments in response surface designs. Specifically, an alternative strategy for assigning pseudorandom numbers is proposed which is more efficient than Cooley and Houck's strategy, especially when more than two factors are involved.

ADAPTIVE SPECTRAL METHODS FOR SIMULATION OUTPUT ANALYSIS, Phillip Heidelberger and Peter D. Welch, IBM T. Watson Res. Labs., Yorktown Hts., NY.

This paper addresses two central problems in simulation methodology: the generation of confidence intervals for the steady state means of the output sequences and the sequential use of these confidence intervals to control the run length. The variance of the sample mean of a covariance stationary process is given approximately by $p(0)/N$, where $p(f)$ is the spectral density at frequency f and N is the sample size. In an earlier paper we developed a method of confidence interval generation based on the estimation of $p(0)$ through the least squares fit of a quadratic to the logarithm of the periodogram. This method was applied in a run length control procedure to a sequence of batched means. As the run length increased the batch means were rebatched into larger batch sizes so as to limit storage requirements. In this rebatching the shape of the spectral density changes, gradually becoming flat as N increases. Quadratics were chosen as a compromise between small sample bias and large sample stability.

In this paper we consider smoothing techniques which adapt to the changing spectral shape in an attempt to improve both the small and large sample behavior of the method. The techniques considered are polynomial smoothing with the degree selected sequentially using standard regression statistics, polynomial smoothing with the degree selected by cross validation, and smoothing splines with the amount of smoothing determined by cross validation. These techniques were empirically evaluated both for fixed sample sizes and when incorporated into a sequential run length control procedure. For fixed sample sizes they did not improve the small sample behavior and only marginally improved the large sample behavior when compared with the quadratic method. Their performance in the sequential procedure was unsatisfactory. Hence, the straightforward quadratic technique recommended in the earlier paper is still recommended as an effective, practical technique for simulation confidence interval generation and run length control.

STATISTICAL ANALYSES OF SIMULATION OUTPUT DATA: THE STATE OF THE ART, Averill M. Law, Management Sciences, Univ. of Arizona, Tucson, AZ.

In this paper we present a state-of-the-art survey of statistical analyses for simulation output data in the case of a single simulated system. The various statistical problems associated with output data analyses such as start-up bias and determination of estimator accuracy are described in detail. We then discuss the best available techniques for addressing these problems, as well as topics for future research. The paper concludes with a discussion of how developments in simulation languages, computer graphics, and computer execution speed may affect the future of output analyses.

ACHIEVING A CONFIDENCE INTERVAL FOR PARAMETERS ESTIMATED BY SIMULATION, Nabil Adam, Grad. School of Business, Rutgers Univ., Newark, NJ.

This paper presents a procedure for determining the number of simulation observations required to achieve a preassigned confidence interval for parameters estimated by simulation. This procedure, which is simple to implement and efficient to use, is compared with two other methods (by Fishman and by Law and Carson) for determining the required sample size in a simulation run. The empirical results show that this procedure gives good results in the precision of estimated parameters and in sample size requirement.

BRIEF COMMENTS ON RECENT BOOKS

Simulation in Business Planning and Decision Making, Thomas H. Naylor (ed.), Vol. 9., No. 1 in the SCS Proceedings Series.

The chapters fall into three major divisions, Models for Production Planning, Models for Marketing Planning, and Financial Planning Models.

Operations Research: Shaum's outline series in engineering, Richard Bronson.

This volume is noteworthy for its total exclusion of Simulation.

#1 - BALLOT FOR NEW COLLEGE OFFICERS

Check the space next to candidate's name or write in an alternative name in space provided.

Chairman: William E. Biles ☐

write-in _____

Vice Chairman: Bruce W. Schmeiser ☐

write- in _____

Secretary/Treasurer: Lee Schruben ☐

write-in _____

Mail ballot to Averill M. Law, Management Information Systems, Graduate School of Business, University of Arizona, Tucson, Arizona 85721.

#2 - BALLOT FOR COLLEGE AWARD FOR BEST SIMULATION PAPER IN *MANAGEMENT SCIENCE*

Three papers have been nominated for selection as the best paper on simulation published in the last volume (27) of *Management Science*. The ballot below contains the authors names, paper titles, and bibliographic information.

The definition of "best" was intentionally left undefined by the committee that set up the award two years ago, so that each member of the College could use whatever criteria desired.

Each member of the College may cast one vote for one paper. Although not necessary, any comments about your selection are appropriate and appreciated.

1981 "Best Paper in Simulation and Gaming" *Management Science*

Vote for one only.

☐ S.S. Lavenberg and P.D. Welch, "A Perspective on the Use of Control Variables to Increase the Efficiency of Monte Carlo Simulations," *Management Science*, 27, 3 (March 1981), 322-335.

☐ B. A. Rosenbaum, "Service Level Relationships in a Multi-echelon Inventory System," *Management Science*, 27, 8 (August 1981), 926-945.

☐ M. Oral, J. Malouin, and J. Rahn, "Formulating Technology Policy and Planning Industrial R&D Activities," *Management Science*, 27, 11 (November 1981), 1294-1308.

MAIL TO: Bruce Schmeiser, School of Industrial Engineering, Purdue University, West Lafayette, IN 47907 by September 1, 1982.