THE INSTITUTE OF
MANAGEMENT SCIENCES

NEWSLETTER OF THE
TIMS COLLEGE
on
SIMULATION AND GAMING

AVERILL LAW and BRUCE SCHMEISER, EDITORS

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CHAIRMAN'S COLUMN

First, I would like to express my pleasure of having been elected chairman of the TIMS College on Simulation and Gaming and I hope we can continue to move the College forward. Second, I would like to thank Bill Schmidt for the excellent job he did as chairman for the last two years. I believe his major accomplishment was obtaining a Department of Simulation in the journal of Management Science. This took a considerable amount of effort and it was not visible to most members of the College. George Fishman has been appointed editor of this new department by the Editor-in-Chief, Martin Starr. Let us all support our new department by sending high quality manuscripts to George and providing fast response to any refereeing asked of us.

I have proposed to the council of the College, and they have approved, the idea of the College publishing Bibliographies and Monographs on Simulation and Gaming. We plan, if possible, to have the bibliographies sent to each member of the College at no cost and to charge only a nominal fee to others for them. The bibliographies can be in any methodology areas, e.g., random number generation or output analysis, or in application areas, e.g., health systems, computer systems, or inventory systems. Those of you having bibliographies or desiring to prepare one, please contact me.

The monographs we desire to produce will be primarily for use in the practice of simulation, although we will not restrict

ourselves to only these. An example of a monograph could be on random number generation. This monograph would describe the different methods of generating random numbers and give tested computer code that can be used in different languages and different word length computers. In order to encourage monographs, the author (or authors) will receive 25% of the selling price of their monograph. Those of you who desire to prepare a monograph, please foreward to me a detailed outline of a proposed monograph. Outlines for a monograph will be reviewed prior to suggesting that a manuscript be prepared. After a manuscript has been written, it will also be reviewed before being accepted for publication by the College. We hope to produce several high quality monographs. These proposed monographs provide an opportunity for practicioners, faculty, graduate students, etc. to be of service to their profession by preparing them.

The College is continuing their normal activities such as sponsoring sessions at the ORSA/TIMS Meetings and being one of the cosponsors of the Winter Simulation Conference. As something new, the College is going to sponsor a reception (mixer) at the ORSA/TIMS Meeting in Milwaukee. Details of these activities can be found elsewhere in the newsletter.

Let us all become involved with the College and if you have any ideas you would like to have the College do, please contact any of the College Officers.

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COLLEGE MEETING

The TIMS College on Simulation and Gaming will hold a meeting Monday, October 15, during the TIMS/ORSA meeting in Milwaukee. Plan to attend. We will be discussing the monograph series, as discussed by Bob Sargent in the Chairman's Column elsewhere in the newsletter.

MIXER AT MILWAUKEE ORSA/TIMS MEETING

In an attempt to get members of the College together socially, we are planning a mixer for Tuesday evening, October 16 at the fall ORSA/TIMS meeting in Milwaukee. We don't know where it will be held yet, but the location and time will be announced at most of the simulation sessions Monday and Tuesday We will also post it on the announcement board at the meeting.

Hope to see many of you there.

NATIONAL MEETINGS

The TIMS College in Simulation and Gaming remains active in supporting three national meetings: fall national TIMS/ORSA, spring national ORSA/TIMS, and the Winter Simulation conference.

We are one of seven organizations supporting the 1979 Winter Simulation Conference, December 3-5, in San Diego. The College supports the conference with both time and money, although we have at least broken even on it in the past. The programs range from tutorials to state-of-the-art sessions. Attendance has been around 400 the last couple of years, with individual sessions commonly attracting 50-100 persons. The quality is usually high, so plan to attend if you can.

The college supports the national ORSA/TIMS meetings primarily by organizing about three sessions per meeting. We then coordinate several other sessions composed of contributed papers. Averill Law, vice-president in charge of meetings, lists the following seven sessions for the Milwaukee meeting October 15-17, 1979.

Session MAA11, Monday AM, 8:30-10:10, "Simulation I," Chairperson: Bruce Schmeiser

Session MAB11, Monday AM, 10:25-12:05, "Industrial Applications of Computer Simulation," Chairperson: D. Brent Bandy

Session TAA11, Tuesday AM, 8:30-10:10, "Simulation of Computer Systems," Chairperson: Yen W. Chao

Session TPA03, Tuesday PM, 1:45-3:25, "Simulation and Data Analysis," Chairperson: Bruce W. Schmeiser

Session TPA11, Tuesday PM, 1:45-3:25, "State-of-the-Art Surveys of Simulation Methodology, I," Chairperson: Averill M. Law

Session TPB11, Tuesday PM, 3:40-5:20, "State-of-the-Art Surveys of Simulation Methodology, II," Chairperson: Averill M. Law

Session WAB11, Wednesday AM, 10:25-12:05, "Simulation II," Chairperson: Thomas J. Meaders

In addition there are sessions on simulation handled by other groups, such as Stanley Erickson's "Military Combat Simulation, I and II."

FALL AIEE CONFERENCE

The fall AIIE conference will be held at the Hyatt Regency-Houston on November 14-16, 1979. A series of five presentations relating to simulation have been designed to provide fundamental information concerning the diverse aspects of simulation for a general audience. The following sessions have been assembled by Dr. Alan Pritsker.

"Problem Solving using Simulation",
Robert E. Shannon

"Simulation Modeling",
Joe Mize

"Simulation Languages",
C. Dennis Pegden

"Applications of Simulation",
Steven Duket

"Statistical Analysis of Simulation Outputs",
James R. Wilson

1979 NATIONAL COMPUTER CONFERENCE

Bill Biles, council member of the college, Richard Schuman and Burnett Moody spoke in Joe Talavage's session on Simulation of Industrial Processes in June at the 1979 National Computer Conference.

NEW ADDRESS

This issue of the newsletter is about a month later than I planned, which I will neatly blame on establishing my new address. Any items for future issues of the newsletter can now be sent to me at

Professor Bruce Schmeiser

School of Industrial Engineering

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West Lafayette, IN 47907.

NEW CO-EDITOR OF THIS NEWSLETTER

Averill Law has recently resigned as co-editor of the newsletter. We thank him for his efforts over the last three years. Averill continues to be active in the college as Vice-President in charge of meetings.

Lee Schruben will replace Averill beginning with the next issue. Lee is on the IEOR faculty at Cornell. As mentioned elsewhere in the newsletter, Lee will handle paper abstracts and various other duties.

ABSTRACTS OF RECENT PAPERS

Beginning with this issue, we are printing abstracts of recent papers. As can be seen below, response to our call for abstracts in the last issue was good, although it can be much better. Send in abstracts for your own papers or abstracts of papers you think are interesting. Particularly desirable are good papers published in relatively obscure places and recent technical reports.

To reduce our effort, it would be helpful if you send the information in the format used below. However, if that takes too much time, just send us a copy of the paper and we'll take care of it.

As announced elsewhere in this newsletter, Lee Schruben will be co-editor of the newsletter beginning with the next issue. He will handle the paper abstracts, among other things. Therefore, send your abstracts for future issues to

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The abstracts received follow. If you want a copy of a paper, please write directly to the author at the address given. (In the case of multiple authors, the address given is the current address of the first author, unless noted otherwise.)

"Regenerative simulation with internal controls," Donald L. Iglehart and Peter A. W. Lewis, *Journal of the Association for Computing Machinery*, 26, 2 (April 1979), 271-282.

A new variance reduction technique called internal control variables is introduced. This technique is to be used in regenerative simulations. The idea is to identify a sequence of control random variables, each one defined within a regenerative cycle, whose mean can be calculated analytically. These controls should be highly correlated with the usual quantities observed in a regenerative simulation. This correlation reduces the variance of the estimate for the parameter of interest. Numerical examples are included for the waiting time process of an M/M/1 queue and for several Markov chains.

"A new probability distribution with applications to Monte Carlo robustness studies," M. E. Johnson, G. L. Tietjen, and R. J. Beckman, Informal report LA-UR 78-1453, Los Alamos Scientific Laboratory, P. O. Box 1663, Los Alamos, New Mexico 87545.

A new probability distribution is presented which offers considerable potential for providing stochastic inputs to Monte Carlo simulation studies. The proposed distribution is used in investigating the robustness of some tests of hypothesis, some tests of normality and some estimators of location.

"Bivariate distributions with given marginals and fixed measures of dependence," Mark E. Johnson and Aaron Tenenbein, Informal report LA-7700-MS, March 1979, Los Alamos Scientific Laboratory, P. O. Box 1663, Los Alamos, NM 87545.

Two systematic approaches are given for constructing continuous bivariate distributions with specified marginals and fixed dependence measures. Both approaches are based on linear combinations of independent random variables and result in bivariate distributions which can attain the Frechet bounds. The dependence measures considered are the grade correlation coefficient and Kendall's τ. The joint distributions obtained are compared to those of M. Frechet (1951), R. L. Plackett (1965), D. Morgenstern (1956), and G. Kimmeldorf and A. Sampson (1975). Applications to testing for sensitivity in simulation models are discussed.

"Regression metamodels for generalizing simulation results," Jack P. C. Kleijnen, *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-9, 2 (February 1979), 93-96.

Abstract—Generalization of simulation results is needed for sensitivity analysis, optimization, "what-if" questions, etc. To meet these needs, several types of metamodels are presented. One type is discussed in detail, namely, linear regression models. These models can represent interactions among input variables of the simulation program and can be validated through statistical tests. Experimental designs can be utilized for efficient and systematic exploration of possible system variants. The approach is compared to Meisel and Collins' piecewise linear models. References to practical applications are included.

"Generalization of simulation results: Practicality of statistical methods," J. P. C. Kleijnen, A. J. van den Burg, and R. Th. van der Ham, *European Journal of Operations Research*, 3 (1979), 50-64.

The major purpose of this paper is to evaluate the practical use of statistical techniques in both the generalization or analysis of simulation results, and the design of simulation experiments. This problem is investigated with the help of a real-life system, namely the container terminus of ECT in Rotterdam. This system is modeled by a simulation program. The relationship between the simulation response and its input variables is modeled by a linear regression model: metamodel or auxiliary model. The paper summarizes regression analysis including generalized least squares which might be used for simulation responses with non-constant variances. The validity of the postulated regression metamodel is tested statistically: F- and t-statistics. The selection of the situations to be simulated, is done through experimental design methodology, permitting both quantitative and qualitative factors. The statistical techniques apply not only to simulation but also to real-life experiments.

"IMPACT revisited: A critical analysis of IBM's inventory package 'IMPACT'," J. P. C. Kleijnen and P. J. Rens, *Production and Inventory Management*, Journal of APICS, 19, 1 (First Quarter 1978), 71-90.

Service and costs are evaluated under IMPACT, an IBM package for inventory management. First the fundamental aspects of IMPACT are determined for a single article. Simulation shows that IMPACT gives too much, expensive service. Four causes for this overservice are detected. IMPACT also permits the joint replenishment of a group of articles. Simulation shows that in joint ordering the desired service is not realized. Therefore, correction factors are developed. The performance costs and service, of single and joint replenishments, are compared in an extensive simulation experiment, in which seven factors are varied. Joint ordering is found to give lower ordering and inventory costs and better service.

"SMALL-JOBS-FIRST: A combined queuing, simulation, and regression analysis," F. Keyzer, J. Kleijnen, E. Mullenders, and A. van Reeken, FEW Research Memorandum, February 1979, Tilburg University, Department of Economics, Postbus 90135 - 5000 LE Tilburg, NETHERLANDS.

Key-punching in our university computing center is modeled as a queueing simulation with two servers (typists) and three priority classes: small, medium, and large jobs. The 90% quantiles of the waiting times per job class are estimated for different borderlines X and Y between the three job classes. An overall criterion function is formulated, quantifying tradeoffs among the waiting times of each job class. Several regression models are investigated, expressing the quantiles as functions in the class limits X and Y. Optimal class limits are determined applying a numerical search algorithm. The resulting optimal limits have been implemented.

"Simulation in the evaluation of management information systems: An overview and evaluation," Jack P. C. Kleijnen, FEW Research Memorandum, December 1978, Tilburg University, Department of Economics, Postbus 90135 - 5000 LE Tilburg, NETHERLANDS.

The economic evaluation of Management Information Systems may be based on the following theories and techniques: control theory, System Dynamics (discrete-event) simulation, and gaming. Applications of these approaches are summarized. Advantages and disadvantages of the various approaches are presented.

"Importance sampling in systems simulation: A practical failure?." A. C. M. Hopmans and J. P. C. Kleijnen, FEW Research Memorandum, April 1978, Tilburg University, Department of Economics, Postbus 90135, 5000 LE Tilburg, NETHERLANDS.

A network of servers, known as a grading in telecommunication engineering, is simulated in order to estimate the probability of a customer getting "blocked" (all servers busy). Since blocking is a very rare event (1 % to 5 % chance), importance sampling or IS was considered for reduction of the simulation variance. The basic idea of IS is first explained by means of a non-dynamic system. For dynamic systems a method was proposed by Bayes in 1970, which is related to the "virtual measures" published by Carter and Ignall in 1975. For simple queuing systems, we derive the resulting variance, using the renewal (regenerative) property of such systems. For our practical "grading" system several alternative importance regions are investigated. For practical reasons we choose to start an importance region immediately after a call gets blocked (no renewal state). The analysis and simulation experiments for the resulting estimator, yielded the estimated optimal length of the importance region and the optimal number of replications of the region. Unfortunately resulting net variance reduction turned out to be negative.

"Regression estimators in simulation," Anton C. M. Hopmans and Jack P. C. Kleijnen, FEW Research Memorandum, Tilburg University, Department of Economics, Postbus 90135 - 5000 LE Tilburg, NETHERLANDS.

Dividing a simulation run into subruns yields average input values per subrun which deviate from their known expectation. This information can be used to improve the estimated simulation response: control variates or regression sampling. To derive the statistical properties of the new estimator, regression analysis is examined for stochastic independent variables and misspecified regression models. It is shown that the usual, crude estimator is biased.

Assuming a local linear approximation, the crude estimator remains biased "ex-post", whereas the regression estimator becomes unbiased. Moreover, the variance of the regression estimator is smaller under each of three intuitivily acceptable conditions.

"Financial benefits of accurate information: A simulation experiment with an IBM business game," J. P. C. Kleijnen, same address.

As a tool for investigating the effects of information in tactical and strategic decision-making, the IBM "Management Decision-Making Laboratory" is used. This business game is a dynamic simulation model requiring strategic and tactical decisions, based on imperfect knowledge. The game provides a model for three companies and the environment (market) in which these companies compete with each other. A game is a simulation model accepting decisions made by human participants. We, however, use computerized players, i.e. a computer program, called DUMMY, makes the decisions which provide the input for the IBM game. This DUMMY like human players, does not know the exact structure and parameter values of the game. It does not try to derive an optimal solution; instead it uses heuristic decision rules. First we experiment with inaccurate information on production unit cost, next with inaccurate information on sales. Using statistical techniques we find that inaccurate information has a significant linear effect on the growth of total assets, and on the average return on investment and market share. The experiment may be seen as a first step towards general conclusions, or as an illustration of a general methodology for ad-hoc real-life studies.

"Simulation of Non-homogeneous Poisson processes with degree-two exponential polynomial rate function," Peter A. W. Lewis and G. S. Shedler, March 1977, Naval Postgraduate School, Code 55 Lw, Monterey, CA 93940 (to appear in *Operations Research*)

A new method for generating a non-homogeneous Poisson process with rate function $\lambda(t)=\exp(a_0+a_1t+a_2t^2)$ is given. The method employs a rejection technique, in conjunction with a method for simulating the non-homogeneous Poisson process with rate function $\exp(\gamma_0+\gamma_1t)$ by generation of gap statistics from a random number of exponential random variables with suitably chosen parameters. The proposed method for the degree-two exponential polynomial model is more efficient than time scale transformation of a homogeneous Poisson process, and should be applicable to other rate function models.

"Simulation of nonhomogeneous Poisson processes by thinning," Peter A. W. Lewis and G. S. Shedler, to appear in *NRLQ*.

A simple and relatively efficient method for simulating one-dimensional and two-dimensional nonhomogeneous Poisson process is presented. The method is applicable for any rate function and is based on controlled deletion of points in a Poisson process whose rate function dominates the given rate function. In its simplest implementation, the method obviates the need for numerical integration of the rate function, for ordering of points, and for generation of Poisson variates.

"A probability distribution and its uses in fitting data," John S. Ramberg, Edward J. Dudewicz, Pandu R. Tadikamalla, and Edward F. Mykytka, *Technometrics*, 21, 2 (May 1979), 201-214.

A four-parameter probability distribution, which includes a wide variety of curve shapes, is presented. Because of the flexibility, generality, and simplicity of the distribution, it is useful in the representation of data when the underlying model is unknown. A table based on the first four moments, which simplifies parameter estimation, is given. Further important applications of the distribution include the modeling and subsequent generation of random variates for simulation studies and Monte Carlo sampling studies of the robustness of statistical procedures.

"Computer generation of bivariate gamma random vectors," Bruce W. Schmeiser and Ram Lal, July 1979, School of Industrial Engineering, Purdue University, West Lafayette, IN 47907.

The use of bivariate gamma distributions in simulation modeling is considered. A family of algorithms is given, any member of which can be used to generate random bivariate vectors having any gamma marginal distributions and any theoretically possible correlation, both positive and negative. Computational considerations are discussed, including the selection of parameters to provide regression curves consistent with the modeler's needs. A modification which is easier to implement and provides most, but not all, correlations is also given. Finally the use of these algorithms to generate first order autoregressive time series is discussed.

"Squeeze methods for generating gamma variates," Bruce W. Schmeiser and Ram Lal, School of Industrial Engineering, Purdue University, West Lafayette, IN 47907. (revised version June 1979)

Two algorithms are given for generating gamma distributed random variables. The algorithms, which are valid when the shape parameter is greater than one, use a uniform majorizing function for the body of the distribution and exponential majorizing functions for the tails. The algorithms are self-contained, requiring only U(0,1) variates. Comparisons are made to four competitive algorithms in terms of marginal execution times, initialization time, and memory requirements. Marginal execution times are less than those of existing methods for all values of the shape parameter, as implemented here in FORTRAN.

"Another versatile family of probability distributions," Bruce W. Schmeiser and Ram Lal, December 1978, School of Industrial Engineering, Purdue University, West Lafayette, IN 47907.

A new four parameter family of probability distributions is described. Special cases include Bernoulli trails, uniform, power series, exponential, triangular and Laplace (double exponential) distributions. Statistical properties, parameter determination and random variate generation are discussed.

"Controlling initial bias in simulation experiments," Lee W. Schruben, Technical Report No. 391, April 1979, Department of Industrial Engineering and Operations Research, Cornell University, Ithaca, NY 14853.

A general technique for controlling initialization effects in simulation output is developed using statistical control methods. Both scalar and multivariate output are considered. An example of an actual simulation study is presented for illustration.

"A coverage function for interval estimators," Lee W. Schruben, Technical Report No. 410, February 1979, Cornell University, Ithaca NY 14853.

A random confidence coefficient is introduced. The distribution function of this variate has an interpretation that can be used to illustrate confidence interval robustness. It is suggested with some examples, that this function be used in the analysis of empirical interval estimator studies. Some approaches for determining appropriate sample sizes in such experiments are also presented. The examples are short studies of four techniques for constructing confidence intervals for the mean of a simulation response.

"Systems of frequence curves generated by transformations of logistic variables," P. R. Tadikamalla and N. L. Johnson, Institute of Statistics, Mimeo Series No. 1226, May 1979, Department of Statistics, Chapel Hill, NC. No abstract in paper.

FIRST CLASS

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