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Simulation education (Panel)

Chair:
Voratas Kachitvichyanukul
Industrial and Management Engineering
The University of Iowa
Iowa City, Iowa 52242

Panelists:
George S. Fishman
David H. Withers
Thomas Clark
Bruce Schmeiser
Lee Schruben

Introduction

Computer simulation is now being used in numerous scientific disciplines and is one of the most widely used operations research technique today. It is taught in computer science, engineering, operations research, and business school curricula. However, the content of simulation courses are so vastly different from one institution to the next that one would have difficulty recognizing it by just looking at the content of the courses. Moreover, the simulation field is generally not part of the core curriculum in most of the academic programs. It is the focus of this panel to discuss about simulation education in general and more specifically, the content for simulation courses and on a broader scale the content of a curriculum in simulation.

This session brings together outstanding individuals who are actively involved in simulation community. The panel members are chosen to achieve proper balance of various orientations in simulation such as engineering, operations research, business school, and industry. The balance of this paper contains the position statement of each panel member addressing specific aspects of simulation education.

We have all heard comments by some scientists and engineers outside the field that reflect a negative image of simulation. This is manifested and reinforced by the advertisements for simulation packages with such claim as "no programming required", "no simulation knowledge necessary". It is our hope that this panel discussion will be a step toward a more positive image of the simulation profession.

Author's Biography

Voratas Kachitvichyanukul is an assistant professor in Industrial and Management Engineering at The University of Iowa. He holds a BS in Chemical Engineering from National Taiwan University, an M Eng from the Asian Institute of Technology, and a Ph D in Industrial Engineering from Purdue University.

Dr. Kachitvichyanukul's current research interests are the development of integrated simulation environment, simulation optimization on parallel computers, special purpose simulation language, random variate generation, and industrial applications of simulation and artificial intelligence techniques. His consulting experiences are in information systems analysis and manufacturing systems modeling. His research publications have appeared in Journal of Statistical Computation and Simulation, Communications of the ACM, Simulation, ACM Transactions on Mathematical Software, Computers in Industrial Engineering, and IIE Transactions. He is a member of ACM, TIMS, SCS, and IIE.

Voratas Kachitvichyanukul
Industrial and Management Engineering
The University of Iowa
Iowa City, Iowa 52242
U.S.A.

(319) 335-5931
aegvorwy@uiamvs.bitnet

POSITION STATEMENT

George S. Fishman
Department of Operations Research
University of North Carolina
Chapel Hill, NC 27514

Modeling, programming languages and statistical issues have long been acknowledged as the three essential components of a well rounded education in simulation. Although each of the past four decades has seen a different emphasis placed on each component, most contemporary teachers of simulation would agree that exposure to all three areas in the classroom remains the hallmark of a thoughtful simulation course.

In recent years, the advents of personal microcomputing and of parallel computing have created new environments in which to perform simulation that were totally absent a decade ago. However, merely transferring the conventional philosophy for doing simulation to new environments fails to acknowledge the special opportunities that they offer and in some cases can be detrimental to one's productivity.

With regard to personal microcomputing, software suppliers have rushed forth to supply a myriad of simulation packages. Many exploit the interactive graphical capacity that the microcomputing environment encourages and this development is to be applauded. However, one needs to question whether looking at all the visual perspectives of a hypothetical factory layout is appropriate as content for a simulation course or is more appropriate for a course on computer aided design. Likewise, time devoted to animation reduces time that can be devoted to more fundamental simulation issues.

What then are the potential benefits of graphics in a microcomputing environment? Students can benefit substantially by observing at least two kinds of graphical output. First, a graphical display of buffer statuses in a queueing simulation with finite buffers cogently reveals to the student where bottlenecks exist. Second, graphical displays of summary sample output distributions of interest, generated as a simulation evolves, give considerably more concreteness to the abstract concepts of statistical inference which, otherwise, most students find tedious to study. More importantly, in the new environment of multitasking wherein a microcomputer runs two or more simulation programs simultaneously, the ability to compare graphical displays simultaneously allows the student to learn how to make an early decision on which of several design options are worth persuing without running all options for complete runs. Teaching this skill to students is a new challenge to the teacher of simulation. Although statistical tools and graphical tools are available separately today, considerable work remains to integrate these two areas in a way that provides a protocol for teaching that can survive scientific scrutiny.

Random number generation in simulation education has emerged as a topic requiring careful qualification in a microcomputing environment. Much of the well established and useful advice for sampling on a mainframe computer with extended word length has been transferred to the microcomputing environment with little, if any, recognition of what happens to results when processing occurs in the usually shorter word length environment. Students need to be shown examples from real life, and these are not hard to find. Also, they need to be shown how and encouraged to question the efficacy of each new random number generator they encounter on a PC. until they can satisfy themselves that it meets minimal standards of acceptability. For many years, this was a persistent problem on main frames which fortunately has come under reasonably good control today. However, the problem remains prevalent on personal computers and students need to know how to cope with it.

My remaining remarks concern parallel or concurrent computing, an area in which considerable simulation work occurs and in which substantial room exists for research to determine how to realize the potential improvements in computational efficiency. Here the implications of scheduling events differ markedly from the environment of sequential computing, and students should have, at least, some understanding of what these distinctions are. Random number generation also needs attention here. Whereas a direct adoption of standard techniques for sequential machines rarely runs into statistical problems, it creates a critical section in a parallel program that generally precludes realizing an increase in computational efficiency. New methods have been proposed for dealing with this problem, including the concepts of pseudorandom trees and leapfrogging. But each of these can have detrimental effects on the statistical quality of the random numbers, and again students need to be made aware of the potential dangers.

In summary, I would like to encourage the development of comprehensive teaching materials that expose students to the benefits of microcomputing and parallel computing and sensitize them to the new issues that need to be resolved when working in these environments.

Author's Biography

George Fishman is professor and chairman of the Department of Operations Research at the University of North Carolina at Chapel Hill. His principal interest is the development of statistical methodology applicable to the analysis of output from discrete event digital simulation models. He is the author of *Concepts and Methods in Discrete Event Digital Simulation* published by Wiley in 1973 and of *Principles of Discrete Event Simulation* published by Wiley in 1978. He is a frequent contributor to the operations research and statistical literature on this topic. At present, he is working on variance reduction methods for network reliability estimation and on the influence of concurrent processing on simulation program structure. Professor Fishman is the past simulation departmental editor for Management Science and is a member of the Operations Research Society of America, the Institute of Management Science and the American Statistical Association.

George S. Fishman
Department of Operations Research
University of North Carolina
Chapel Hill, NC 27514

(919) 962-6997

POSITION STATEMENT

D. H. Withers
IBM
Application Systems Division
Atlanta, GA

Simulation is certainly mature enough to warrant the rank of scientific/academic discipline. My position is based on a very complete definition of simulation, not merely random variate generation, nor queueing models, not computer languages. Simulation is the total process of:

- Problem synthesis,
- Model formulation,
- Model order reduction,
- Computer implementation and validation
- Experimental design, and
- Analysis and presentation of the results.

First we will review the skills, education and technologies required for each of the components of simulation as defined above:

Problem synthesis

requires domain knowledge of the problem area (electrical engineering, industrial engineering, emergency medicine, movie theaters, manufacturing, etc.) The requisite skills and experience in these areas comes from established academic programs and suitable experience. In order to complete this step of simulation, one also needs formal training or experience in problem solving - determining the "real" issues, defining an appropriate objective function, and finding the true decision variables from the long list of variables. Simulation education must start here - with problem solving skills.

Model formulation

requires skills and experience in extracting the domain knowledge from the experts. The hard part here is to refrain from imposing a solution methodology on the problem before the problem is understood and communicated from the first step. There are two prerequisite educational components: (1) exposure to a wide variety of simulation technologies (continuous/discrete/mixed, event-driven/time-driven, object-oriented/ process-oriented, etc.) and (2) exposure to a very broad engineering/scientific knowledge base so the simulation practitioner can communicate with the people with the problem. In addition, this step requires very intensive training and some experience in structured modeling methods. Again, a variety of tools need to be available (Geoffrion's structured modeling, Ziegler's multifacetted modeling, Yourdon's methods, IDEF techniques, queueing networks, etc.)

Model order reduction

is perhaps the most demanding technical task. There are statistical methods, but they are not usually useful until well after the model has been pruned to include significant components and exclude spurious components. Pruning requires domain knowledge and an in-depth understanding of the structure of the modeling methodology used in the problem.

Computer implementation and validation

requires knowledge and experience in software engineering, not just programming. There are a variety of methodologies. It is significant that this field is not yet mature, and will not be so for the foreseeable future. The tools and the technologies are advancing continuously. This step also requires proficiency with the particular programming or simulation system used for the problem. The step is not complete until validation is accomplished.

Validation requires comparison of the model AND the inputs to problem conditions, and satisfactory mapping of outputs to the expected conditions. This step requires the structured modeling skills from above as well as advanced statistical analysis proficiency.

Experimental design

is a classical branch of statistics, but takes on a special flavor for application to simulation. There are no uncontrolled variables, so there should be no unexplained variability! Training in design of experiments for simulation requires this particular extra dimension.

Analysis of the simulation results

requires much more than elimination of initial effects and construction of confidence intervals. The results must be translated into the language of the problem domain. The knowledge required to understand the problem at the beginning is just as important at this step, but a key additional skill is absolutely required. One must be able to COMMUNICATE the results to whoever needs them - verbally and in writing.

A summary

of the above steps indicates that simulation may be a discipline at the graduate level. An undergraduate foundation is required in the problem domains. A combination of engineering, mathematics, statistics, computer science, and communications (listening, speaking, and writing) is required on top of the undergraduate base.

The multi-disciplinary aspects of this field suggest an approach similar to that used for manufacturing systems engineering - a multi-disciplinary department with joint appointments to Simulation and to the traditional departments.

Author's Biography

David H. Withers is a Senior Planner with the IBM Applications Systems Division in Atlanta, Georgia. He began his current assignment in 1987 after managing the Product and Process Analysis group at the IBM Thomas J. Watson Research Center. He served on active duty as a Coast Guard Cutter. He was named Outstanding Junior Coast Guard Officer by the Defense Supply Association. Mr. Withers received a B. S. in Engineering from the U. S. Coast Guard Academy, and M. S. degrees in Mathematics and Computer Science from Rensselaer Polytechnic Institute. His work has emphasized the development of mathematical models of physical systems, especially those relating to product reliability and service delivery. He joined IBM in 1969 and has had both technical and management assignment at Burlington, VT, Lexington, KY, Franklin Lakes, NJ, and Yorktown, NY. He received an IBM Outstanding Contribution Award and an IBM Information Products Division Award. His current interests are requirements specifications for Computer Integrated Manufacturing systems. He is a member of a National Research Council Study Committee ACM, SIGNUM, ORSA, TIMS, and TIMS College on Simulation.

D. H. Withers
Application Systems Division/IBM
1500 RiverEdge Parkway
P. O. Box 28331
Atlanta, GA 30358-0331

(404) 956-5289

Simulation Education in the Business College

Thomas D. Clark, Jr.
Department of Information and Management Sciences
College of Business
The Florida State University
Tallahassee, Florida 32306-1042

There are three traditional levels of education in the typical business college as in any other academic discipline. The undergraduate curriculum is directed at a student's specific study area. Simulation, if it is taught, generally is imbedded in a discipline specific course such as decision support systems, expert systems, financial modeling or accounting systems. The material is strongly related to the use of simulation to solve specific problems. The topic is introduced in the operations research course in a more quantitative or analytical curriculum.

At the masters level, introductory simulation courses are widely found. Most of them are language dependent and provide a strong application rather than theoretical orientation. The students are from a variety of backgrounds and disciplines, especially in an MBA program. In an MS program, the average student is better prepared mathematically, so more theory about random number and variate generation and analysis of output is found.

At the Ph D level, advanced courses are offered but the orientation is on the use of simulation as a research tool in a specific discipline such as production or operations management, information systems, marketing or finance. In quantitative or decision analysis programs, advanced courses are offered that are typical of those found in operations research and engineering curricula.

Discussion Orientation
1. Theoretical Modeling
2. The Systems Science Paradigm
3. Languages
4. Operating Environments

Author's Biography

Thomas D. Clark, Jr. is an Associate Professor of Information and Management Sciences and Director of the Center for Information Systems Research at The Florida State University. He has been active in the Winter Simulation Conference for ten years as an author, session chairman, and track chairman. He has taught a variety of computer simulation courses at the graduate level and has supervised over sixty masters and doctoral theses and dissertations that have employed simulation analysis. He had extensive experience in logistics management before joining a university faculty and has published a variety of papers using simulation in study of logistics and operations management systems. His current research interests include investigation of a methodology to value management information, the structure of multi-echelon service operations and the nature of decision support system evolution. He is a member of ACM, ORSA, TIMS, SIM, SCS, DSI, and SGSR.

Thomas D. Clark, Jr.
Department of Information and Management Sciences
College of Business
The Florida State University
Tallahassee, Florida 32306-1042

(904) 644-5508
tclark@fsu.bitnet

Simulation Education

Bruce Schmeiser
School of Industrial Engineering
Purdue University
West Lafayette, IN 47907, U.S.A.

Those in the simulation community usually closely identify with one of the following three orientations:

a. practitioner (produces simulation analyses)
b. developer (produces simulation tools)
c. researcher (produces simulation theory and methodology).

Good education for each level includes a sense of and an appreciation for the other levels.

Author's Biography

Bruce Schmeiser is a professor in the School of Industrial Engineering at Purdue University. He received his undergraduate degree in mathematical sciences and master's degree in industrial and management engineering at The University of Iowa. His Ph.D. is from the School of Industrial and Systems Engineering at the Georgia Institute of Technology. He is the *Operations Research* area editor in simulation and has served in editorial positions of *IIE Transactions, Communications in Statistics, B: Simulation and Computation, Journal of Quality Technology, American Journal of Mathematical and Management Sciences*, and the *Handbook of Industrial Engineering*. He is the past chairman of the TIMS College on Simulation. He represents ORSA on the Winter Simulation Conference Board of Directors, currently serving as chairman. His research interests are the probabilistic and statistical aspects of digital-computer stochastic simulation, including input modeling, random variate generation, output analysis, and variance reduction.

Bruce Schmeiser
School of Industrial Engineering
Purdue University
West Lafayette, IN 47907, U.S.A.

(317) 494-5422
schmeise@gb.ecn.purdue.edu

Position Statement

Lee W. Schruben
School of Operations Research and Industrial Engineering
Cornell University
Ithaca, NY 14853

For the purposes of this discussion, at a high level it makes sense to view the topics in a simulation course as being in three categories: modeling, computing, and analysis. Under the heading of modeling are such topics as simulation worldviews, languages, input process identification, verification, etc. In the computing area are algorithms for list management, random number generation, event timing, variate generation, data base management, programming for variance reduction,and so forth. Simulation analysis includes the design of experiments (for both estimation and optimization), simulation data collection, statistical inference, validation, estimator variance reduction techniques, etc.

The relative emphasis a curriculum places on each of these areas largely determines the level of practitioner their students become. If a student is expected to primarily program other people's models but not use these models themselves then it might make sense to devote most of course on modeling concepts and computing techniques. If the the student is likely to use simulation in actual decision making then a heavy emphasis on analysis is critical.

A person is not a simulation practitioner unless they are competent in each of the above areas at a reasonable depth; balance is vital. It is unfortunate for our entire profession that there are people who profess to be simulation experts when they know little more about the field than how to code models in a particular simulation language. There are many vocational training programs in simulation languages that masquerade as education. Students who have taken only a single "language-level" simulation course typically are unable to read the literature in their own field and have only a rudimentary appreciation of the technical aspects of a simulation program. In the past, I have taught and taken many such courses and argued their merit; however, as my knowledge of simulation grew I became convinced that under no circumstances should a simulation language be the focus of a university course...anywhere! I have heard colleagues argue that their students are not bright enough to handle technical and analytical topics. I admit to being spoiled by exceptionally smart and motivated students. However, I am not sure that a language course is better than no course in simulation. Simulation languages should be taught by those best suited...people who sell and support the particular language.

College-educated simulation practitioners who do not know how to test and modify a random variate generation algorithm, can not efficiently and correctly design, run, and draw inferences from a simulation experiment, and can neither read nor appreciate simulation research literature have been short-changed by their professors; they should ask why! Such students have been given a powerful tool but are ignorant of how it works or its proper use...A University should educate not merely train.

Author's Biography

Lee Schruben is on the faculty of the School of Operations Research and Industrial Engineering at Cornell University. He received his undergraduate degree in engineering from Cornell University and a Master's degree from the University of North Carolina. His Ph.D. is from Yale University. Prior to coming th Cornell, he was the Associate Director of the Health Systems Research Division and an Assistant Professor of Pharmacology in the Medical School at the University of Florida. Before going to graduate school, he was a manufacturing systems engineer with the Emerson Electric Co. in St. Louis, Missouri. He has taught or taken courses in GPSS, SIMSCRIPT, and SLAM and found them to be a lot of fun. His research interests are in the statistical design and analysis of large scale simulation experiments. His consulting activities have been primarily in the area of manufacturing systems simulation. He is the past chairman of the TIMS College on Simulation and is also a member of ASA, ORSA, and SCS where he serves on several editorial boards.

Lee W. Schruben
School of Operations Research and Industrial Engineering
Cornell University
Ithaca, NY 14853

(607) 255-9133
fx9j@cornella.bitnet