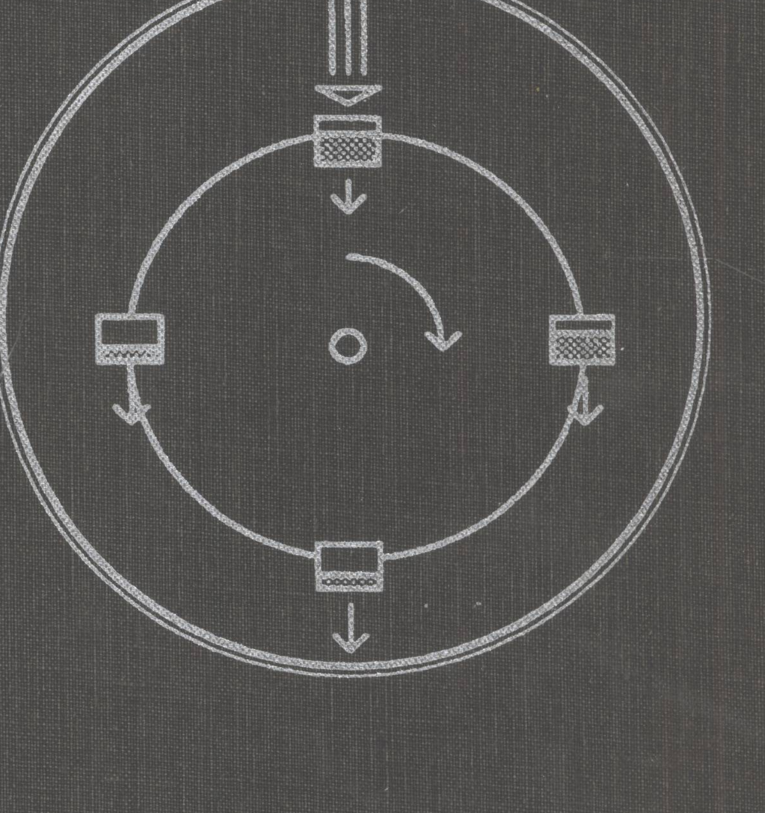
International Conference on Simulation in Engineering Education (ICSEE'94)

Edited by
Charles E. Knadler, Jr.
Hamid Vakilzadian

Simulation Series
Volume 26
Number 1



THE SOCIETY FOR COMPUTER SIMULATION
ISBN #: 1-56555-066-8

International Conference on Simulation in Engineering Education (ICSEE'94)

Proceedings of the 1994 Western Multiconference

January 24-26, 1994
Radisson Tempe Mission Palms Hotel
Tempe, Arizona

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Simulation Series
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Conference Sponsor
The Society for Computer Simulation

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The Society for Computer Simulation
P. O. Box 17900
San Diego, CA 92177 U.S.A.

ISBN 1-56555-066-8

PRINTED IN THE UNITED STATES

Preface

On behalf of the Program Committee of the 1994 International Conference on Simulation in Engineering Education, welcome to ICSEE 94. This conference brings together academic, research, and industrial practitioners to share insights into current engineering practices and techniques and to develop a vision for bringing the best to our students.

The new advances in computational sciences and technology and the development of sophisticated mathematical tools have made a significant contribution toward promoting the methodological techniques in mathematical and computer modeling. This gives us an opportunity to teach our students new techniques and methodologies in simulation, and gives students the best possible tools in preparation for real-world challenges.

The collection of papers in this volume contains many excellent contributions from our colleagues in academia and industry whose efforts of exploring, writing manuscripts, and preparing presentations are easily overlooked.

The success of this conference is primarily the combined result of all the authors, session chairs and associate chairs, organizers, SCS, and Dr. George Zobrist, General Chair for 1994 Western Simulation Multiconference.

Special thanks and appreciation are also given to the program committee. It is pleasure to acknowledge Dr. Don J. Nelson, Dr. John L. Ballard, and Mrs. ChloeAnn Danielson for their help and support. Also, thanks to Dr. Stanley Liberty, Dean of the College of Engineering and Technology, and to Dr. Rodney J. Soukup, Chairman of the Department of Electrical Engineering, for providing me with the time and support for this conference.

We also grateful to the American Society for Engineering Education, ASEE, and the IEEE Education Society for their continuing cooperation and support of this conference.

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TEACHING MANUFACTURING SIMULATION AT THE GRADUATE LEVEL

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ABSTRACT

Experience in teaching a new manufacturing simulation course to graduate students in Industrial Engineering is described. Students are required to have experience in simulation modeling prior to enrolling in the course. The course focuses on issues that arise in using simulation to assist in design, analysis, and process improvement activities for manufacturing systems.

INTRODUCTION

Simulation methodologies are widely used in the design and analysis of manufacturing systems. Automated or semiautomated systems, in particular, can present many difficulties to the simulation analyst. These difficulties range from understanding and capturing the interrelationships between components of the system to data collection and analysis to interpretation of the results from the model.

It is difficult to address these issues in a first course on simulation modeling and analysis. Typically, such a course covers the fundamentals of simulation modeling and analysis, including input data analysis, output analysis, and concepts such as event scheduling, random variate generation, model building, and verification (Taha, 1993; Ballard and Glismann, 1993). Of necessity, many models built in this first course are simple: objectives are well-defined, sample data is provided, and the problem description fits neatly on a single page or is taken from problems at the end of a textbook chapter.

Although the typical first course is very well suited to teaching simulation fundamentals, it leads students to harbor unrealistic expectations concerning the ease of requirements identification, data analysis, modeling, and verification for real systems, as well as the time required for such activities. Funke, in a panel on manufacturing simulation (Norman, 1992) states "As simulation practitioners in manufacturing environments, we must recognize that the level of detail required to evaluate most 'real life' systems far surpasses that of academic examples and software tutorials. A successful model design represents the best balance between functionality, level of detail, constraints, and flexibility to conduct experiments". Numerous papers have dealt with pitfalls of simulation and simulation project management (examples include: Musselman, 1992; Sadowski, 1991, 1992; Law and McComas, 1986). Musselman (1983) expresses the following concern: "While ... graduates are often good modelers, they are seldom good practitioners".

A graduate level course was developed to focus on manufacturing simulation; the course was described in a previous presentation (Medeiros, 1993), and was taught for the first time in the Fall semester of 1993. As this paper is being written, the course is in progress. Therefore, initial experiences in teaching the course will be discussed in the paper, and more complete information will be provided during the presentation.

COURSE OBJECTIVES AND OUTLINE

The course was designed for graduate students in Industrial Engineering with previous experience in simulation modeling, either from a first simulation course as summarized above or from practical experience in simulating manufacturing systems. The goals of the course are to prepare students to better understand, model, and analyze manufacturing systems, and to identify research issues in manufacturing simulation. The course outline is shown in Figure 1. Homework assignments and a semester project are

1. Types of Manufacturing System Models
2. Simulation Project Management
3. Problems in Modeling Manufacturing Systems
4. Randomness in Manufacturing Systems
5. Levels of Detail in Modeling
6. Verification, Validation, and Sensitivity Analysis
7. Performance Measures and Steady State Analysis
8. Languages and Simulators for Manufacturing Simulation
9. Innovative Uses of Simulation in Manufacturing

Figure 1. Outline of the Course

required. Originally, it was planned that the homework would be based on case studies and the project would be chosen by the student.

Because of the requirement that students have previous simulation experience, there is no need to teach a language in the course. The course emphasizes other activities required to conduct a successful simulation projects and modeling issues important in manufacturing, such as machine failure, system control, and automated material handling.

COURSE IMPLEMENTATION

Work in the course to date has covered the first 3 topics and part of the fourth; students have completed one assignment and are finishing a second. The outline has been revised to incorporate topic 8, languages and simulators, earlier in the semester. The topics covered to date are described below.

Types of Manufacturing System Models

The system development life cycle and the role of simulation at the various stages of development were considered. Fox and Halladin (1991) provide an overview of this topic with examples from various steps in the project life cycle. Class discussion focused on the types of models and appropriate level of detail required at the different stages in system design, installation, and operation. Fuller's (1989) discussion of workcell simulators provided a contrast to the discrete event simulation approach and stimulated discussion on additional levels of detail in modeling beyond discrete event simulation, as well as linkages between discrete event simulation and other types of modelers.

Simulation Project Management

This portion of the course concentrated on the principles of developing project objectives, defining appropriate levels of detail consistent with the objectives, and formulating a conceptual model. The topics of verification, validation, and experimentation were briefly discussed for completeness, but will be treated at greater length later in the semester. The project management paper by Sadowski (1992) served as a focal point for the discussion, and his approach was compared to that of Fox and Halladin (1991).

First Assignment

During the first two topics, the students were given a homework assignment to construct a model of the IE Department's flexible manufacturing system. This automated manufacturing system consists of a storage and retrieval system for raw material and finished parts, a cart-on-track material transport system with 8 carts holding up to 4 parts each, a rotational cell, a prismatic cell, and an assembly cell. The rotational cell consists of a turning center, machining center, and a robot for machine loading and unloading. The prismatic cell contains a machining center and a robot, while the assembly cell contains an assembly robot and some fixturing. Four part types are produced, one of which consists of two pieces that require assembly. The objective of simulating the flexible manufacturing system related to capacity planning: students were to determine if adding a new turning center would significantly improve system throughput, and if so, to determine how the machining cells should be reconfigured to accommodate the new machine.

Problems in Modeling Manufacturing Systems

The experience of students in developing this first model led directly into the third topic: problems in modeling manufacturing systems. A brief discussion of issues in modeling advanced manufacturing systems can be found in Evans and Biles (1992), and such issues are also discussed in several of the previously cited papers. Problems in manufacturing system modeling and analysis were categorized into three areas: general simulation issues, manufacturing systems issues, and automated systems issues (Figure 2).

The general simulation issues were of two types: project management related and software engineering related. In the former category were concerns such as developing a model at the appropriate level of detail for the objectives and time required to conduct the modeling and analysis process. The latter category included language support for the system life cycle through hierarchical models and code reusability, as well as utilization of modern software engineering concepts such as object oriented programming.

The general manufacturing systems issues dealt with system control, system analysis, and use of the simulation models. Control issues included the difficulties in modeling pull systems, machine breakdowns or failures, and adaptive decision making by system operators and supervisors. Systems analysis issues included understanding system transient behavior, particularly when the system does not reach steady state due to product mix changes, fluctuating customer demand, and low inventory levels. Also discussed was the difficulty of using simulation models in on-line decision support and optimization applications.

General Simulation Issues
- appropriate level of detail
- difficulty of model creation
- model reusability
- support for software engineering principles
- support for hierarchical model development

Manufacturing Systems Issues
- process selection, job scheduling, routing
- response to system breakdowns or failures
- analyzing transient shortages and bottlenecks
- on-line decision support or optimization
- mixed shift scheduling, mixed push-pull
- incorporating human decision making

Automated Manufacturing Systems Issues
- complex interrelationships among resources
- resource contention and deadlock
- modeling automated material handling systems
- modeling control systems
- separating system description from control logic

Figure 2. Problems in Modeling Manufacturing Systems

Automated manufacturing systems present an additional range of difficulties associated with a large number of interacting resources, possibilities for deadlock, and complex automated material handling systems. Particularly for such systems, the lack of separation between control logic and system description complicates the task of modeling controller behavior and evaluating alternative control logic.

Randomness in Manufacturing Systems

This topic includes considerations of sources of randomness, types of data required and possible options for obtaining the data, data analysis, input distribution fitting, and models of machine failures. Hatami (1990) provides an excellent discussion of data requirements during the project life cycle, particularly as related to the analysis of synchronous or asynchronous flow lines. The panelists' preliminary statements in Kelton (1990) provide an overview of issues in specifying input distributions. Law (1990) considers alternative models for machine downtime, and Vincent and Kelton (1992) reflect on the general problem of distribution selection.

Second Assignment

The second homework assignment, concurrent with the third and fourth topics, required modifying the model of the flexible manufacturing system to incorporate machine failures and to include control issues related to scheduling parts and balancing workload in the system.

OBSERVATIONS AND DISCUSSION

A central feature of the course is that students are required to independently build and analyze models of a manufacturing system. This has led to fruitful discussion in class on issues that many of the students had not previously considered. Originally, it was planned to use case studies for the homework assignments. That approach was eliminated because of the difficulty of conveying the complexity and multitude of issues to be found in an actual system.

It is a great advantage to have a system in-house that students can study and experiment with. For example, in undertaking homework 1, some students conducted experiments with the robots and material storage and transport systems under various scenarios to evaluate the effects on overall system throughput. This homework was a first experience for several of the students in observing a system, asking questions concerning its operation, and developing a conceptual model; some were very uncomfortable with the lack of a written problem statement. There was much discussion concerning the appropriate level of detail for the model and which subsystems could be assumed, to a first approximation, to have little impact on system performance. Other issues included resource interactions and deadlock avoidance, maintaining appropriate levels of work in process, and how the choice of language affected the model (models were written in GPSS, SIMAN, and SLAM).

Many of the problems raised by the students related to methods of modeling certain features and the assumptions they made in choosing a method. Comparatively little attention was given to model verification and output analysis. Some of the models contained minor logic errors. Since the same model was enhanced for the second assignment, the students were required to correct and verify their models, as well as to consider the effects of variability due to machine failures. Other issues emerging during the second assignment included code reusability, difficulties inherent in modeling system control, and alternative methods of modeling machine failures.

After each assignment, the students are asked to provide anonymous written feedback on their perceptions of the course. Student feedback after the first assignment was generally enthusiastic. Many noted that the issues raised were new to them. A few students perceived a shortage of technical literature in manufacturing simulation, a lack also noted by the instructor. Some students expressed frustration that the first assignment was too vague, that they didn't know what to include in the model, and that building the model took too long. Others recognized that the purpose of the assignment was to encourage them to think about the process of simulation modeling. One student expressed a desire to work with more types of systems and models; methods of meeting this need are currently being investigated.

A number of students expressed particular interest in studying material handling systems. This interest and the progression toward more detailed models later in the project life cycle has led to moving topic 8, simulators and languages for manufacturing systems, earlier in the semester. The AutoMod software will be used for detailed modeling of material handling in the flexible manufacturing system. Simple AutoMod models can be built without writing code, thereby illustrating the concept of a manufacturing simulator. More complex models can be used for a more detailed representation of the cell as well as to illustrate the process orientation used by some simulation languages. Students will also investigate the use of 3D animated graphics in model verification.

Plans are for the remainder of the course to proceed as originally structured. More details on this will be provided during the presentation.

SUMMARY

Practitioners have recognized that one course in simulation modeling is insufficient preparation for conducting simulation studies of manufacturing systems. It is not possible to capture all the intricacies of a real world simulation problem in an academic environment, but students can gain an appreciation of the problems they will face and learn methods for conducting a successful simulation study through a course such as described in this paper. In addition, many interesting research issues arise in the process of analyzing and modeling manufacturing systems, especially in the areas of systems control, decision support, and alternative approaches to language design to support manufacturing applications.

A single graduate course in simulation cannot cover the full scope of issues. This course complements two other IE Department graduate courses: statistical analysis of simulation output, and using simulation models for design. The combination provides a strong skill set in simulation technology, methodology, and applications.

REFERENCES

Ballard, J. L., and C. L. Glismann. 1993. "The Role of the Manufacturing Simulator in the Industrial Engineering Curriculum," *International Conference on Simulation in Engineering Education*, C. E. Knadler, Jr., and H. Vakilzadian (eds.), 273-277.

Evans, G. W., and W. E. Biles. 1992. "Simulation of Advanced Manufacturing Systems," *1992 Winter Simulation Conference Proceedings*, J. Swain, D. Goldsman, R. Crain, and J. Wilson (eds.), 163-169.

Fox, J. G., and S. K. Halladin. 1991. "Effective Application of Simulation in the Life Cycle of a Manufacturing Cell." *Proceedings of the 1991 Winter Simulation Conference*, B. L. Nelson, W. D. Kelton, and G. M. Clark (eds.), 411-417.

Fuller, C. 1989. "The Next Generation of Manufacturing Simulation." *Proceedings of the 1989 Winter Simulation Conference*, E. A. MacNair, K. J. Musselman, and P. Heidelberger (eds.), 840-842.

Hatami, S. 1990. "Data Requirements for Analysis of Manufacturing Systems Using Computer Simulation." *Proceedings of the 1990 Winter Simulation Conference*, O. Balci, R. P. Sadowski, and R. E. Nance (eds.), 632-635.

Kelton, W. D., (chair). 1990. "Alternative Approaches for Specifying Input Distributions and Processes (Panel)," *Proceedings of the 1990 Winter Simulation Conference*, O. Balci, R. P. Sadowski, and R. E. Nance (eds.), 382-386.

Law, A. M., and M. G. McComas. 1986. "Pitfalls in the Simulation of Manufacturing Systems." *Proceedings of the 1986 Winter Simulation Conference*, J. Wilson, J. Henriksen, and S. Roberts (eds.), 539-542.

Medeiros, D. J. 1993. "Analysis of Manufacturing Systems Using Simulation: A Proposed Course," *International Conference on Simulation in Engineering Education*, C. E. Knadler, Jr., and H. Vakilzadian (eds.), 17-21.

Musselman, K. J. 1992. "Conducting a Successful Simulation Project," *1992 Winter Simulation Conference Proceedings*, J. Swain, D. Goldsman, R. Crain, and J. Wilson (eds.), 115-121.

Musselman, K. J., (chair). 1983. "Practitioners' Views on Simulation." *Proceedings of the 1983 Winter Simulation Conference*, S. Roberts, J. Banks, B. Schmeiser (eds.), 169-173.

Norman, V. B., (chair). 1992. "Simulation Practices in Manufacturing," *1992 Winter Simulation Conference Proceedings*, J. Swain, D. Goldsman, R. Crain, and J. Wilson (eds.), 1004-1010.

Sadowski, R. P. 1992. "Selling Simulation and Simulation Results," *1992 Winter Simulation Conference Proceedings*, J. Swain, D. Goldsman, R. Crain, and J. Wilson (eds.), 122-125.

Sadowski, R. P. 1991. "Avoiding the Problems and Pitfalls in Simulation." *Proceedings of the 1991 Winter Simulation Conference*, B. L. Nelson, W. D. Kelton, and G. M. Clark (eds.), 48-55.

Taha, H. A. 1993. "Pitfalls in Teaching Discrete-Event Simulation," *International Conference on Simulation in Engineering Education*, C. E. Knadler, Jr., and H. Vakilzadian (eds.), 237-241.

Vincent, S. G., and W. D. Kelton. 1992. "Distribution Selection and Validation," *1992 Winter Simulation Conference Proceedings*, J. Swain, D. Goldsman, R. Crain, and J. Wilson (eds.), 300-304.

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TEACHING MANUFACTURING SYSTEMS SIMULATION TO AN INTERNATIONAL AUDIENCE

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ABSTRACT

Simulation modeling is becoming an increasingly common analysis technique for study of manufacturing systems. Technology advancements, competitive pressures and favorable exposure have caused simulation to become one of the premier tools of industrial engineers, operating managers and others looking to improve their methods of production. Although developing nations are often viewed as being technologically backward, many organizations in these areas have recognized the value of simulation and are making an effort to spread the technique among their local businesses. Several modes or vehicles have been effective in promoting simulation in these areas and transferring the technology to manufacturing applications. Several factors impact on the success of this transfer, some with direct parallels in the experience of the developed nations and others unique to developing areas or even specific cultures.

INTRODUCTION

As simulation becomes an easier-to-use and more accessible tool for engineers, students, managers and university faculty, it is also starting to move into the hands of nations and areas where the business climate may be very different from that in the countries where simulation has traditionally been used. As this trend continues, the problems encountered may be similar or may be quite different from those we have seen in the past. The success of simulation in these countries is a multi-faceted challenge that needs to be understood before attempting to simply transplant past experience. This level of understanding requires that we know how the technology is transferred, including the institutions affecting the transfer, their methods for spreading the word and the target audience.

MODES OF TRANSFER

In order to understand the spread of simulation outside of countries where the technology has developed and been actively used, we must understand the mechanisms available to facilitate transfer of the technology across political and cultural borders. Although the flow of technology and techniques among simulationists in the developed areas of the West has led to new advances in the state of the art, we will focus primarily on the teaching and introduction of simulation in those areas commonly called developing nations. Even here, there are widely differing approaches to simulation, ranging from no exposure to aggressive efforts to use dynamic modeling as a means of improving industrial competitiveness.

Simulation is widely taught in the U.S., Canada, Western Europe and other areas at similar levels of economic development. Few educational institutions in these nations that offer degree programs in Industrial Engineering, Manufacturing Engineering, Operations Research or similar disciplines do not provide at least one simulation course. Business or management schools generally have simulation courses as well, especially those with Operations Management or Decision Science departments. At minimum, most students are exposed to simulation in the form of a module within an introductory survey course in these disciplines.

In developing nations, on the other hand, the exposure of students to simulation tends to be much less certain. Schools in the newly industrialized countries (NICs), such as Mexico normally do offer a simulation course at the undergraduate level, at least in their engineering programs. Many of the faculty members have received post-graduate training in the U.S. or Europe and tend to use as teaching tools those simulation languages that they learned during the course of their own studies. Business-related programs in these areas are less frequently involved in simulation, possibly because their students receive less exposure to programming techniques than their engineering counterparts.

Industrial Engineering programs in the less developed areas may not even offer a simulation course. In some cases, exposure is limited to review of a chapter on uses of