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PANEL: SIMULATION - PAST, PRESENT AND FUTURE

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ABSTRACT

This panel examines the progress and promise of simulation in areas of education, research and software. The panelists bring the varied perspectives of modelers and researchers, industry, academia and government.

1 INTRODUCTION

Why do we find the future so fascinating? From *2001: A Space Odyssey* to *Animal Farm*, people find it interesting to contemplate changes in technology and culture that one might expect in the future. Simulationists are no different: the future of simulation is a frequent and popular topic at our conferences. This session is one in a continuing set of speculations on the future of our field. In this session we draw on our past and present to see what it might suggest about the future. Our panelists have backgrounds in academia, industry and government, and they will each describe their own view of what has been and/or what is to come in simulation. Of course, a thorough treatment of simulation's past, present and future would take hours and volumes. Presented here is a sampling of many possible discussions.

2 ROBERT SARGENT

Accomplishments and current issues in various aspects of simulation will be presented. We first discuss that simulation as a problem solving method has and continues to be used in a wide variety of application domains and for solving various types of problems. Next, we note that the steps in the methodology of conducting a simulation study have remained the same since the early days; however, how each of these steps is performed has changed over time and continues to change.

The changes in how the steps are performed are due to methodology research in simulation and new computer technology. Visual interactive modeling is primarily used for modeling today using the same world views that were developed in the early days. There are good random number and random variate generators currently available; however research continues on these. The variable-time increment time flow mechanism is the one commonly used today and there are good event list processing algorithms available. Verification and validation have received major attention but continue to need research. Analysis methodology has and continues to be developed. Much is known about output analysis for analyzing means but not near enough is known for other types of estimates. Much research is needed and is continuing in comparison of alternatives, metamodeling, and optimization. Variance reduction research is needed for certain classes of problems; primarily those having rare events and models that require excessive computation time.

Major changes have occurred over time in simulation languages and these will continue to change in the future due to methodology research in simulation and changes in computer technology. Parallel simulation seems to have reached a plateau in terms of development and has never become popular in use. There is interest in distributed interactive simulation, primarily by the military. The field of simulation has made major contributions to both computer science and statistics. These include the concepts of object-oriented programming, the process concept, and the entity/attribute/set concept that have had major impacts in computer science and the development of random number and variate generators and various techniques in analysis methodology that are extremely useful in statistics.

Two current and important topics that are forcing functions for simulation research are complex models and large-scale simulations. These affect all areas of simulation resulting in the need for research in each of the areas. A topical area not mentioned above is the management of simulation studies. How does the size of a simulation project affect how a project should be managed and also what affect does project size has on the methods and techniques used in the various steps of the simulation methodology. These have received little research and this author believes that much research is need regarding these issues. (There are large differences in a simulation study requiring one person for a couple of months and a simulation project requiring several man-years of effort over a two or three year period.) In the modeling of complex systems, how should modeling be performed and what type of modeling capabilities are needed are examples of research needed in the modeling area. Other research topics regarding large-scale simulations or simulations that contain complex models are the development of new methods and techniques for efficient computation and for analysis.

3 PAUL FISHWICK

Modeling is one of the primary components of simulation. Just as for computer programs, there is a sequence of actions that must take place, with feedback loops along the way: 1) specifying requirements for the entire analysis process; 2) building one or more models to satisfy these requirements; 3) executing models, and 4) analyzing model output. There are numerous aspects to modeling, but one that pervades the process is model representation: how are models crafted and displayed? Therefore, a study involving the future of simulation should include the future of model design and representation. How will we design models as technology marches forward into areas encapsulating ever-smaller and ever-faster circuits? The issues involving the future of model representation will touch on everything from levels of visual abstraction to new ways in which to represent text-based mathematical notation.

Modeling is a term that means one thing if you are modeling a sailing vessel, but seems to mean something else if you slap some equations together. One of the historical reasons for creating models for out of typographic symbols is one of pure economy--it takes too long to construct continuous or discrete-event models out of clay, wood, paper, and glue. However, with the revolution associated with display devices, the pushes in areas such as augmented reality and pervasive computing, we should reconsider how we build and notate our models for the future. At the University of Florida, we have constructed a framework called RUBE to assist users in exploring novel model representations, and the ways in which the models are simulated.

RUBE begins with the idea that flexible model authoring can begin with ordinary 2D and 3D design software. By using such software, it is possible to customize and personalize notation. For example, a queue can be represented by a box or by something that more clearly reflects the application (i.e., a model of a machine facility and its queue of parts). We are using open source software to build these models: SodiPodi for 2D, and Blender for 3D. Script-based dialogues are set up to allow users to associate arbitrary icons and objects with their proper semantic functions. RUBE becomes a kind of general purpose toolkit for generating new model types, complete with 2D and 3D objects to reflect the interests of a given modeling community.

4 JAMES HENRIKSEN

Panel sessions discussing the future of simulation software have become a regular feature of Winter Simulation Conferences. Every year we hear prognostications offered by vendors and users of simulation software. From users we hear what they'd like to have, and from vendors we get some rough idea of intended avenues of growth. If there were an obvious, direct economic connection between these two, predicting the future of simulation software would be easy. Vendors could simply build things into their products that they knew users would be willing to pay for. Microeconomic systems are inherently self-correcting.

In addition to not knowing what their prospective users are willing to pay for, as software professionals who know their own products and interact with users of their products, vendors tend to develop their own (sometimes independent) ideas of what's important. In the next two sections, I'll present (1) a list of "motherhood" goals, i.e., things that everyone can agree are laudable goals, and (2) my own, somewhat more controversial ideas on what I think simulation software vendors should be doing.

4.1 Goals

Everyone can agree that improvements in the following areas are desirable:

- Ease-of-Use,
- Reusability,
- Scalability,
- Interoperability / "Plug-In" Support,
- Productivity,
- Promotion/Support of Collaborative Modeling,
- Supporting Component-Based Modeling,
- Building Libraries of "Canned" Models,
- Integrating Simulation Software with
  - Database Tools,
  - Supply Chain Software,
  - ERP Software,
  - Browsers and other very widely used tools.

I believe a software vendor's primary goal should be to maximize the following expression:

$$\frac{Functionality \times Ease-of-Use}{Cost \times Complexity}.$$

A product can have all the functionality one could ever need, but if its features are too hard to use, cost too much, or are unnecessarily complex, the product will fail. Consider the Microsoft-dominated world of PC operating systems. Each successive release of Windows adds many new features, but does so at non-trivial cost and at the expense of massive increases in complexity. Microsoft attempts to mask increased complexity by providing "smart" tools, e.g., "wizards", that help users navigate their way through the complexity, but when the "smart" navigation aids fail, one is often left with problems of staggering complexity.

Ease-of-use is difficult to quantify. It may not only vary over the course of a simulation project; it may undergo startling discontinuities. For example, product A may be very easy to use in the early stages of a project, but as one adds modeling detail and complexity, product A's ease-of-use may decline as it gets harder and header to shoehorn modeling requirements into the product's worldview. On the other hand, product B may be much harder to use in the early stages of a project (too many things to learn before you can get started), but when the going gets tough, product B may be much more capable than product A. If these characteristics were known in advance, a user could simply choose the easiest-to-use product that is capable of doing the job. In the worst case, a user may choose a product and make very rapid progress to the presumed 90% completion point, only to find that the product lacks the capability to complete the project. In this case (the so-called "90 percent syndrome"), a user must either compromises, or choose another product.

4.2 My View

I believe that simulation software vendors need to abandon the "feature wars" and focus on capabilities rather than features. What's the difference between a feature and a capability? A capability is what it takes to build a feature. For example, a simulation package for modeling material-handling systems may offer a pick list of 20 kinds of conveyors. If you're building a model, and all of your conveyors match one of the 20 possibilities, your job is made easy. However, if you have a single conveyor whose characteristics match none of the 20 available, you have to either (1) choose the closest one, or (2) construct your own out of lower-level capabilities. If lower-level capabilities are not accessible to you, you're probably stuck.

I believe that all vendors need to re-examine the core technologies of their products. There are a number of simulation products whose core technologies haven't changed in a decade. Such products may have experienced a great deal of evolutionary growth in the form of numerous additions of features, but ultimately run the risk of becoming top-heavy. It's amazing to me that Fortran still casts a very long shadow over products whose vendors who spew forth torrents of modern buzzwords, such as "object-oriented," "component-based," etc. How object-oriented can you be when your fundamental mechanism for addressing data is the use of integer array indices?

I believe that that vendors need to prevent the following:

Easiest to Use => Hardest to Modify.

This is the most important problem of all. Let me illustrate. One of my customers is doing some leading edge modeling. By that, I mean modeling that most others have not done, and modeling that certainly has not been done widely enough to be institutionalized in the form of features of a commercial simulation product. My users were visited by a simulation software vendor who in essence stated "Why don't you let us build software features that will make it easier for you to solve such problems? We can make your life a lot easier." Narrowly interpreted, the vendor's assertion is correct. However, in a broader context, it was wrong for two reasons. First, in the two years it would take the vendor to package the required features, my customer would have moved two years downstream. Features have an inherently archival property. They represent a vendor's response to past demand. Non-archival features are developed in anticipation of future demands and are subject to the accuracy of the vendor's vision. Second, use of the vendor's packaged solutions would almost certainly require acceptance of the vendor's modeling paradigm. As my customer put it, "We're in the business of inventing new paradigms. By definition, you can't invent new paradigms using someone else's".

In an ideal world, simulation software vendors should provide easy-to-use solutions for common problems, so their users don't have to reinvent the wheel, but these solutions should be based on user-accessible, lower-level capabilities. This approach offers the dual benefit of showing how (and perhaps even why) prepackaged solutions were developed, but allowing or even encouraging the user to develop his/her own tailored solutions for which the vendor has not provided prepackaged features.

5 JANET TWOMEY

Computer simulation remains at the core of numerous tools for the design and analysis of engineered systems. Basic and applied research in simulation methodology and its use is regularly funded the National Science Foundation. In 2003, 528 new awards related to simulation were made totaling $157,924,693. (Award search can be conducted at http://www.nsf.gov/home/grants/grants_awards.htm).

The Manufacturing Enterprise Systems (MES), Operations Research (OR) and Service Enterprise Engineering (SEE) programs in the Design, Manufacture and Industrial Innovation Division of the National Science Foundation funds basic research in simulation methodology and the application of simulation to solves problems in the manufacturing and service industries. The audience for these programs is typically from the Operations Research, Industrial Engineering, Systems Engineering, and Management Science communities. This talk focuses are simulation research conducted by those communities.

While, the MES, OR and SEE programs have not sponsored special solicitations addressing simulation specifically, the core programs have a significant investment in simulation related research. Between 2001 and 2003, the total investment in active awards by the three programs in simulation methodology and applied simulation was approximately $328,925,443 in 83 awards. However, only a small number of awards have been made that specifically address simulation methodology. Recent topics in simulation methodological research have included, optimization via simulation, simulation tools to evaluate the quality of stochastic optimization methods, and new procedures for discrete-event simulation involving quantile estimators.

This talk will attempt to provide some insights into why simulation methodology has not been a particularly successful area for funding in the MES, OR, and SEE programs. The talk will also offer some thoughts and information on what might be some emerging areas for new investigation. Finally new opportunities for funding will be discussed.

6 RUSSELL BARTON

The WSC proceedings provide one way to look at simulation's past, present and future. The conference history spans more than 35 years, but I will focus on the past six. I'll use these recent conference proceedings to highlight the recent past, look at the present, and make a (small) extrapolation.

The WSC proceedings since 1987 are available to you all electronically, and so I began my survey by considering the 1997 *Proceedings* (Andradóttir et al. 1997). My objective was to compare the contents with the 2002 *Proceedings* (Yücesan et al. 2002) to look for common threads and differences. The similarities and differences over time would provide a crude guide to predicting the future, based on Kogan's *symmetric action principle* (Thomas, Cannon and Barton 1995).

My intent was to examine the contents of the *Proceedings* in five areas: software, general applications, military applications, analysis methodology and modeling methodology. These areas have been represented by tracks at the conference for many years, and they collectively give a substantial indication of where our field has been and where it is going. The distinction between analysis and modeling methodology is a bit blurred, and so I treat these areas as one. Tables 1 and 2 summarize the findings from the two proceedings. I'll discuss the changes and sustained themes area by area.

6.1 Software

Software tutorials have been a key part of the WSC. Major vendors and new developers present descriptions of software capabilities. The table entries are separated into common and unique portions, and the common portion shows the names of well known vendors and their product offerings. The most significant change is the increased presence of web-based simulation software.

6.2 Military Applications

Simulation modeling of operations and logistics are popular and recurring themes in military applications, and these two conferences devoted a significant number of talks to these topics. Other popular topics included metamodeling (I view modeling abstraction as a subset of this category), verification and validation, modeling environments, agent-based models and communication systems. The change from 1997 to 2002 seems to indicate a greater interest in agent-based models, perhaps distributed simulation, and in modeling communications between actors in military campaigns or terrorist acts.

6.3 General Applications

Manufacturing applications are a significant portion of both the 1997 and 2002 proceedings. The applications cover a broad array of other areas as well, including modeling Internet traffic, simulating the behavior of computers, and maintenance operations. Construction engineering and financial engineering are two areas of emphasis in 2002 that received less attention in 1997.

6.4 Analysis and Modeling Methodology

One can view analysis and modeling methodology activities at WSC at two levels: session level and talk level. At the session level, there has been a consistent pattern of topics for a number of years: input modeling, output analysis, metamodels, optimization and selection, parallel and distributed simulation, rare-event simulation, validation, verification and accreditation, and web-based simulation. Within each of these broad areas there are some specialized topics that have had long lives, including batch means, distribution fitting, design of simulation experiments, random number generation and testing, ranking and selection, sensitivity analysis, and variance reduction. One might expect these broad areas and long-lived topics to continue to be of interest. In addition, there appears to be an increasing interest in a number of areas, including the simulation of large scale systems, non-polynomial metamodels, the selection of input models, the sensitivity of the model behavior to input distribution assumptions, and the role of standards in validation, verification and accreditation. other emerging areas of interest include input models for generating dependent distributions, high-dimensional dependent distributions, cross-entropy for tilting, and combinatorial stochastic optimization.

6.5 The Future

Past and present activities indicate that we can expect to see continued interest in software, general applications, military applications, analysis methodology and modeling methodology well into our future. Looking ahead five years from 2002 to 2007, what might we expect to see in the proceedings?

In software, we'd expect to see presentations by many existing vendors on the latest features in their software suites. This might well include distributed and parallel simulation capabilities, and enhancements to the user interface. Changes in input modeling and output analysis capabilities are also plausible, along with enhanced DOE/RSM/metamodeling capabilities and sensitivity/Pareto analysis. We'd also expect a number of new developers to be presenting special capabilities beyond the mainstream simulation packages. What might they be? Based on the past conferences, one might see modeling environments for specialized applications, e.g. construction management, financial engineering.

In general applications, the interest in manufacturing is likely to continue, with significant emphasis on semiconductor manufacturing, construction management, and health applications. In light of current homeland security concerns, it is possible that this will become an important area of emphasis. In spite of the situation on Wall Street, there are many opportunities for simulation applications in accounting and finance, and I expect these areas to be represented in 2007.

Homeland security may also be a focus for military applications in the near future. Simulation models of disease propagation, Internet attacks, and terrorist acts are

Table 1: Software, Military and Applications Sessions at WSC, 1997 and 2002

Topic	1997	2002
Software	Arena, AutoMod, AweSim, ExpertFit, Extend, Micro Saint, ProModel, and others: AIM, ALPHA/Sim, AutoStat, AutoSched, CSIM18, GPSS/H, ISACS+, MedModel, MODSIM III, ProcessModel, Proof, ProSim, QUEST, SiMPLE++, SimProcess, SLX, VisSim, VSE, WITNESS.	Arena, AutoMod, AweSim, ExpertFit, Extend, Micro Saint, ProModel, and others: Credibility Assessment, Flexsim, Simkit, Silk, SSJ, Non-item based tools.
Military	Operations & logistics, V&V, modeling environments, abstraction & metamodels.	Campaign analysis, unmanned aerial vehicles, wide area search, logistics, agent-based models, weapon and communication systems.
Applications	Manufacturing, assembly line, work cell, paint shop, capacity planning, sequencing & scheduling, order-release, backward-planning, flexible manufacturing, inventory management, maintenance, and special computer applications including communications network traffic, simulating ATM networks, simulating parallel computers, simulating the Internet.	Manufacturing, semiconductor, wood industry, business process reengineering, financial engineering, construction engineering (a separate track), simulation-based scheduling (a separate track), sports (soccer championship analysis).

Table 2: Analysis and Modeling Methodology Sessions at WSC, 1997 and 2002

Topic	1997	2002
Analysis	*Session Topics*: input modeling, output analysis (2), selecting the best & optimization, variance reduction techniques, sensitivity analysis, metamodeling, single-run model execution. *Talk Topics*: single run sensitivity, batch means, efficiency of variance estimators, variance reduction, output analysis via bootstrap, jackknife, and Bayesian, Bayesian input modeling, screening, multivariate extreme values, selecting the best, stochastic optimization.	*Session Topics*: input modeling (3), output analysis (2), selecting the best & optimization (2), rare event simulation (2), . *Talk Topics*: ARTA, NORTA, high-dimensional dependent distributions, cross-entropy for tilting, stochastic approximation, combinatorial stochastic optimization, selecting the best, Bayesian characterization of model uncertainty - optimal DOE, batch means, quantile estimation.
Modeling	*Session Topics*: Policies and technologies in modeling and simulation, parallel and distributed simulation, multi-agent systems and simulation, performance measurement in parallel and distributed simulation, web-based simulation, validation, verification and accreditation panel, simulation support environments, advances in modeling methodology.	*Session Topics*: Metamodeling & RSM, parallel and distributed systems, virtual worlds, model setup, XML modeling, open source simulation software, model development, network modeling, very large scale systems, aerospace operations, reuse of simulation components, web-based simulation (separate track).

possible topics in the Homeland Security topic area. At the same time it is very likely that the interest in operations and logistics problems will continue. I expect that agent-based models and distributed simulation will be at least as important in 2007.

It is hard to predict innovations in analysis and modeling methodologies at the detailed level of new technologies. At a broader level, it is safe to assume that past patterns will continue. The WSC 2007 attendee can expect to see sessions on input analysis, output analysis, optimization, approximation, parallel and distributed methods and the design of simulation experiments. What will be the breakthrough methodologies? Meet me at WSC in 2007 and find out.

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