Proceedings of the 1993 Winter Simulation Conference
G.W. Evans, M. Mollaghasemi, E.C. Russell, W.E. Biles (eds.)

ARTIFICIAL INTELLIGENCE AND COMPUTER SIMULATION
---- NOT SUCH STRANGE BEDFELLOWS ----

Roger McHaney

Department of Computer Information Systems
and Quantitative Analysis
University of Arkansas
Fayetteville, Arkansas 72701, U.S.A.

ABSTRACT

Artificial intelligence and computer simulation are two different classes of tools used to tackle similar problems. This paper provides an overview of various applications involving their integration. Some of these applications are expert systems embedded in simulations, intelligent model creation tools, simulation parameter optimizers, expert decisions verifications and AI based simulation languages. The merger of these two technologies appears to be an inevitable and exciting part of computer simulation's future.

1 INTRODUCTION

A 17th century philosopher was reported to have said, "*We are very close to knowing all there is to learn.*" So simple were the dynamics of society in his day that few people took issue with his statement. Today we know that type of thinking to be naive on one hand and possibly arrogant on the other.

One of the first steps in learning is the realization of how much you don't know. The accumulation of new knowledge clarifies how much more is left to learn. It is upon this foundation that many modern decision making aids have been developed.

Computer simulation is one such decision making tool. Its modern roots date back to the 1950's when some of the first computer models were developed (Clymer, 1987). Initially computer simulation, like the hardware and software platforms available at the time, was unwieldy and cumbersome. Problem solving and decision making were time consuming and costly. It wasn't until the late seventies and early eighties that simulation became a reasonable method of analysis.

Once computer simulation was *discovered* by industry, its use proliferated. The number of products cited in Simulation's annual Catalog of Simulation Software increased from 106 in 1986 to more than 200 in 1988. During this time period of expansion and growth more than just the number of users was changing. Many of the underlying objectives for simulation use were also evolving.

Initially most simulation users wrote their models with traditional computer languages such as BASIC, FORTRAN or assembler. Most models were very application specific and used to answer a single question. Many models were treated as one time case studies. Soon specialty languages such as GPSS, SIMSCRIPT, SIMULA and SLAM began to appear on the scene. With added power, modeling became easier and permanent generic libraries containing information about simulated entities were created. Not only did this help reduce the time required in producing the next model, it also established models as knowledge bases. Current simulations became the building blocks for future models. Simulation analysts and consultants involved in repetitive studies of similar types of systems found simulation packages or simulators to be an excellent way to retain knowledge. As lessons were learned, pertinent information was built into a simulator where it could be easily maintained and reused. If an analyst left his or her job, not all of their knowledge and experience left with them. Much of it was retained in the form of reusable simulation code. Because of this, many experts began viewing simulation in a different way.

Although the primary focus of computer simulation has remained on reducing risk in decision making, its secondary role as a knowledge system is becoming more important. Of the 200 simulation software packages cited by Simulation (1988) more than half can be classified as simulators or intelligent simulation packages. Much of the knowledge required to create a specific model type is already present --- built into the package's logic. This helps enable a relatively inexperienced analyst to produce a valid model.

The knowledge base aspect of modeling has not gone unnoticed in literature. In fact, many authors have pointed out the usefulness of simulation in this capacity and paralleled its development with many up and coming artificial intelligence (AI) applications. While not all authorities agree how AI will come to be used by simulation applications, nearly all agree it will be used in some form.

The remainder of this paper will concentrate on specific examples of artificial intelligence activity in the computer simulation community, particularly noting embedded expert systems for decision making within a model, AI-related model creation tools, AI-driven model input parameter optimization and AI-based simulation languages.

2 EMBEDDED EXPERT SYSTEMS IN COMPUTER SIMULATION

Expert system technology is an applied category of artificial intelligence dealing with reproducing an expert's knowledge and behavior using a computerized database (knowledge base). Expert systems embedded in a simulation and knowledge representation are topics currently generating much interest in the simulation field. Many authors (O'Keefe, 1986; Shannon, Mayer and Adelsberger, 1985; and Moser, 1986) have referenced inroads and study taking place in these areas noting the particularly heavy concentration of applications (and potential applications) in manufacturing.

Li, Tang, and Tu (1992) relate how simulation and expert systems have the natural capacity to complement each other. They describe simulation as being "*a numerical technique without the functions of reasoning and symbolic processing*". Expert systems on the other hand are specifically designed for symbolic representation and reasoning. By driving the decision process with an expert system's knowledge base and porting the results into a simulation, the two decision making tools act in a complementary fashion. Better decisions, taking advantage of the strengths found in both techniques, may result (Wildberger, 1992).

Paralleling descriptions of simulation's shortcomings for certain types of decision making in manufacturing applications, management researchers have noted the inability of simulation to adequately represent human decision making processes. As indicated in the manufacturing arena, AI technology appears to hold the key for accurately modeling non-numeric decision processes in management studies.

In their paper *Beyond Garbage Cans: An AI Model of Organizational Choice*, Michael Masuch and Perry LaPotin (1989) detail the development of one of the first computer simulations to use AI methodology as a means of modeling the human decision making process in an organization. Masuch and LaPotin describe limitations associated with modeling human decision making using traditional software approaches and emphasize the advantages AI offers. *"AI"*, they say, *"allows for the creation of inductive models leaving much of the trial and error human behavior intact."* Because of this, AI tools used in conjunction with computer simulation have the potential to advance organizational theory in an entirely different way. Masuch and LaPotin are very optimistic as to the future of AI in simulation applications. In fact, they summarize their study by stating "*simulation produces promising new perspectives on theory production especially when powered with AI-based inference strategies.*" The human factor is better represented and thus more realistic. Because of this, they believe AI and simulation have a definite future together.

Although the notion of embedding an expert system in a simulation model appears sound from a theoretical standpoint, much work needs to be done before a practice such as this becomes routine. Two notable technical problems stand in the way. First, simulations require substantial CPU time per run. The addition of an expert system to an already time-consuming modeling process may not be readily accepted by simulation practitioners. Second, interfaces to many popular modeling languages are clumsy at best and nonexistent or even impossible in many cases. Different integration approaches may need to be investigated. However it should be stated at this juncture; as computers become faster and as AI technology becomes widespread, these difficulties will be surmounted. Expert systems will become commonplace components of simulation studies.

3 INTELLIGENT MODEL CREATION TOOLS

A second usage for AI technology in simulation can be categorized as intelligent model creation tools. Simulations are often built by specialists who rely on experts to describe how systems are to operate. The simulation specialist translates these expert descriptions into code. This process was recognized by many simulation software developers thereby prompting them to create simulators. These simulators trap the knowledge of an expert, allow it to be packaged and sold for use by many people. Developers of simulators have taken two different approaches. One involved trapping simulation expertise so system experts are able to easily create their own models. The second approach trapped system expertise so reasonably experienced simulation analysts could create valid models even if they had no expertise concerning the system being modeled. Since simulators package knowledge with software, they might be considered to be a form of expert system (using the term in a broad form). However, most simulators do not use true AI techniques to represent knowledge or make decisions.

The value and widespread use of simulators as modeling tools have prompted researchers to investigate new and better methods of encapsulating simulation data. True AI-based tools (particularly expert systems) fit so nicely into this application it seems improbable they would be overlooked and they certainly haven't. Sabuncuoglu and Hommertzheim (1989; 1988) report using expert system technology in the development of flexible manufacturing system simulations. Haddock and O'Keefe (1990) discuss the use of AI in the development of an Intelligent Front End or IFE to generate simulation code, execute the model and present valid results. Widman and Loparo (1990) also mention using expert systems to generate simulations and ensure all necessary modeling constraints are in place. Bekely (1988) contends "*the current generation of AI-based aids to simulation is in facilitating the task and making the computer into a convenient tool for model building.*"

Automatic code generation frees the modeler from mundane tasks in model development, particularly in cases when numerous similar models will be developed. Time spent writing code can be used more constructively. Tasks previously performed by simulation language specialists will be put back into the hands of system experts and system users (Coats, 1989). With advantages such as these to be gained by implementations of intelligent model creation tools, there is little doubt that AI and simulation will continue to merge in this area.

4 SIMULATION PARAMETER OPTIMIZATION AND VERIFICATION OF EXPERT DECISIONS

A third use for AI technology in conjunction with computer simulation is to aid in model input parameter optimization. A traditional weakness of computer simulation has been its inability to provide optimal answers. Modeling provides outputs based on data entered into the system. The task of optimization has been left to the simulation analyst.

Several authors (Bengu and Haddock, 1986; Widman and Loparo, 1990) suggest using an expert system to select reasonable ranges of input data to run through a simulation. The resulting outputs would be fed back into the expert system for formulation of additional runs and eventual optimization. This process might even be automated as an additional time saving measure.

Li, Tang and Tu (1992) contend an expert system might utilize simulation software to test the validity of its solutions or decisions. Since expert system reasoning is typically independent of time, the time based algorithms present in simulation may prove to be a good method of validation. Widman and Loparo (1990) discuss the same idea but take it a step further. After various model runs have been completed and the results analyzed by the expert system, they suggest an expert system might have its knowledge base updated by the information *learned*. In this way, future simulations of a similar nature might be started closer to the optimization point.

5 AI BASED SIMULATION LANGUAGES

Future computer simulation languages may include embedded AI-based pieces or complete replacement with AI-based languages which address current weaknesses while retaining current strengths. It is probable both symbolic and numeric solution capability will be available to the modeler. Heuristics, fuzzy logic and "gray zones" will be representable in nonprobabilistic ways. Although mainstream commercial developments in this area appear to be a number of years away, much of the foundation is being laid today.

The Jade Simulation Environment (Unger, Dewar, Cleary and Birtwistle, 1986) currently allows combined model development in five languages --- Ada, C, LISP, PROLOG, and SIMULA. This capability of mixing of symbolic and numeric representation within a single model effectively overcomes shortcomings found in any one of the languages.

In another recent language-related development, Zhang, Weili and Mourant (1990) discuss their simulation environment called SuperCard. SuperCard allows modelers to represent entities as objects which "proceed in the simulation process (via the inference engine) until its goals are achieved". They contend SuperCard allows models, closely representing the symbolic nature of the real world, to be constructed.

All the work being done in the area of AI-Based simulation languages points to the realization that AI and simulation can complement each other in this capacity. The eventual merging of the two technologies appear to be on the horizon.

6 SUMMARY

Computer Simulation and artificial intelligence are not such strange bedfellows. These two classes of tools are used to tackle similar problems. Both offer strengths and weakness to decision makers and analysts. The recognition that these technologies can complement each other is the first step toward an eventual merger. The work being done in this area indicates academic interest is keen and as a result practical application is sure to follow.

REFERENCES

Bekely, G. 1988. "On the Development of Knowledge-Based Systems in Modeling, Simulation and Identification." *Peers and Pioneers (John McLeod, ed).* pp 38-42.

Bengu and Haddock. 1986. "A Generative Simulation - Optimization System." *Computers & Industrial Engineering (10:4).* pp 301-313.

"Catalog of Simulation Software." 1986. *Simulation (47:4)* :152-165.

"Catalog of Simulation Software." 1988. *Simulation (51:4)* :136-156.

Clymer, A. 1988. "Another 'Pioneer' in Simulation Heard From." *Peers and Pioneers (John McLeod, ed).* pp. 16-21.

Coats, P. 1989. "A Banker's Use of Simulation and Artificial Intelligence for Assessing the Economics of Electronic Money Networks." *European Journal of Operational Research (Netherlands) (41: 3).* pp 290-301.

Haddock and O'Keefe. 1990. "Using Artificial Intelligence to Facilitate Manufacturing Systems Simulation." *Computers & Industrial Engineering (18: 3).* pp 275-283.

Li, Tang and Tu. 1992. "An Expert System for the Master Production Schedule." *Computers in Industry (19:1).* pp 127-133.

Masuch and LaPotin. 1989. "Beyond Garbage Cans: An AI Model of Organizational Choice." *Administrative Science Quarterly (34: 1).* pp 38-67.

Moser, J. 1986. "Integration of Artificial Intelligence and Simulation and in a Comprehensive Decision Support System." *Simulation (47:6).* pp 223-229.

O'Keefe, R. 1986. "Simulation and Expert System - A Taxonomy and Some Examples." *Simulation (46:1).* pp 10-16.

Sabuncuoglu and Hommertzheim. 1988. "Expert Systems and Simulation in Flexible Manufacturing Systems." *Computers & Industrial Engineering (15:1-4).* pp 1-7.

Sabuncuoglu and Hommertzheim. 1989. "Expert Simulation Systems - Recent Developments and Applications in Flexible Manufacturing Systems." *Computers & Industrial Engineering (16:4).* pp 575-585.

Shannon, Mayer and Adelsberger. 1985. "Expert Systems and Simulation." *Simulation (44:6).* pp 275-284.

Unger, Dewar, Cleary, and Birtwistle. 1986. "A Distributed Software Prototyping and Simulation Environment: Jade." Proceedings of the Conference on Intelligent Simulation Environments. SCS. San Diego, CA. pp 63-71.

Widman, Lawrence and Loparo. 1990. "Artificial Intelligence, Simulation, and Modeling." *Interfaces (20: 2).* pp 48-66.

Wildberger, A. 1992. "AI & Simulation." *Simulation (59:3).* p 149.

Zhang, Weili and Mourant. 1990. "Simulation and Knowledge Based Objects." *Computers and Industrial Engineering (19:1-4).* pp. 97-101.

AUTHOR BIOGRAPHY

ROGER MCHANEY is currently completing a Ph.D. in Computer Information Systems and Quantitative Analysis at the University of Arkansas. For eight years prior to his return to school he was employed by the Jervis B. Webb Company where he simulated over 100 materials handling systems. Roger is author of the 1991 Academic Press book, *Computer Simulation: A Practical Perspective*.