Proceedings of the 2000 Winter Simulation Conference
J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, eds.

AGENT-DIRECTED SIMULATION – CHALLENGES TO MEET DEFENSE AND CIVILIAN REQUIREMENTS

Tuncer I. Ören
(Panel Chair)

Turkish Science and Technical Research Council, Marmara Research Center
Information Technologies Research Institute
41470 Gebze, Kocaeli, TURKEY

S. K. Numrich

U.S. Naval Research Laboratory
Washington, D.C. 20375-5337, U.S.A.

Adelinde M. Uhrmacher

Department of Computer Science
University of Rostock
D-18051, Rostock, GERMANY

Linda F. Wilson

Thayer School of Engineering
Dartmouth College
Hanover, NH 03755-8000, U.S.A.

Erol Gelenbe

School of Electrical Engineering and 4Computer Science
University of Central Florida
Orlando, FL 32816, U.S.A.

ABSTRACT

The aim of this panel session is to point out the importance of agent-directed simulation, as a scientific concept and technological possibility, to enhance the potential of simulation in both civilian and defense applications. The members of the panel (organized by Dr. Ören) are: Dr. Erol Gelenbe, Dr. S. K. Numrich, Dr. Adelinde Uhrmacher, and Dr. Linda Wilson. The position statements of the panel members are given separately. Ören bases his arguments on the NATO Modelling and Simulation Master Plan. He points out the need to proactively advance simulation science and technology to satisfy the requirements of the sophisticated defense applications. He stresses that, among other methodological advance possibilities, the three categories of agent-directed simulation have to be properly developed and/or tailored for defense applications. Gelenbe's interests include goal-directed knowledge processing abilities of agents in hostile environments. Numrich stresses on the need for command and search agents in defense applications. Uhrmacher states challenges for the users and the simulationists on the need of agents for modelling and agents for testing. Wilson covers four key challenges to agent-directed simulation that are: security, standards in communication, computer resources, and system management and monitoring.

1 AGENT-DIRECTED SIMULATION - CHALLENGES TO MEET DEFENSE REQUIREMENTS (Tuncer I. Ören)

1.1 Motivation

As part of my contribution, I would like to concentrate on defense applications. However, the most important civilian simulation studies can benefit from the agent-directed simulation technology.

It is a well-accepted fact that simulation is already an important tool used by the military and that the advancements in simulation should be closely monitored. See for example NATO Modeling and Simulation Master Plan – Ören was an active member of the NATO Group which developed it – `<http://www.dmso.mil/documentation/policy/nato_msmp/chapter4.html>`, and especially objectives 4 and 5 which recommend, respectively, "Employment of simulation to enhance NATO mission effectiveness" and "Incorporation of technological advances." Especially sub-objectives 5.1 and 5.2 recommend: "Monitoring M&S-related advances" and "Conducting research and development, experiments and pilot projects, as needed, to support Alliance requirements." Sub-objective 5.2 is in harmony with other cases where, while achieving important missions, methodological advances were also realized which in turn accelerated the success of the mission. As an example, one can cite the case of the first nuclear submarine Nautilus, prior to which appropriate techniques to manage large scale projects, especially to control and save time, did not exist. The commander who was in charge of the Nautilus project commended a study to develop such a technique. PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method) were results of such a foresight and also helped tremendously the realization of the submarine ahead of its original schedule.

The way we perceive or conceive reality may direct and/or limit our thoughts and actions. Hence, powerful modelling formalisms may have vital implications on battlefield operations and the operations preceeding them. Leadership necessitates having a broad vista and imagining things yet to be created and implemented to achieve our goals, instead of limiting ourselves assessing the state-of-the-art and by choosing seemingly the best *available* alternative.

It is argued that this type of foresight may help the advancement of military simulation; and agent-directed simulation can be an important possibility to consider.

1.2 Agent-Directed Simulation

Agents are software modules with cognitive abilities that can work as assistants to the users. They can observe and sense their environments as well as affect it. Their cognitive abilities include, (quasi-) autonomy, perception, reasoning, assessing, understanding, learning, goal processing, and goal-directed knowledge processing (Bradshow 1997; Finin; Huhn and Shing 1997; and Weiss 1999).

Agents can contribute to simulation science and technology in the development of capabilities, software tools, and products. Agents and simulation have three types of synergy: (1) agent simulation, (2) agent-based simulation, and (3) agent-supported simulation. *Agent simulation* is the simulation of agents or entities which can be represented by agents. Agent simulation is a natural way of modelling and simulation of intelligent entities, be it natural ones such as humans or engineerd ones such as intelligent platforms, equipments, and destructive devices. *Agent-based simulation* is the use of agents to generate model behavior in simulation. Similar to expert simulation systems and qualitative simulation systems, agent-based simulation offers additional possibilities to numerical simulation. *Agent-supported simulation* is use of agents in simulation support operations which can be front-end and/or back-end user/system interface operations as well as activities related with simulation software.

1.3 Some Potential Benefits

Any science and technology, to be considered useful in military applications, must be helpful in achieving the military requirements. The aim of military forces is –when necessary– to fight and win war(s) and by beeing ready, act as deterrence factors.

Agent-directed simulation, as summarized below, can be useful in military analysis, planning, training, and simulation-based acquisition studies by:

- Modelling intelligent (quasi-) autonomous entities. These can be representation of friendly or enemy individuals, troops, platforms, weapons, and other equipment.

  1. Human behavior modelling.
  2. War-fighter simulation.
  3. Smart weapon simulation.

- Supporting intelligent user/system interfaces.

  1. Scenario description.
  2. Threat representation/analysis.
  3. Environment representation.
  4. Appraisal abilities through understanding and learning capabilities to provide alternative suggestions in stressful conditions.
  5. Intelligent user/system interface to IC4 systems to assess the performance of alternative ways under different operational conditions and threats.
  6. To see the influence of information on combat decision.

- Simulation-based acquisition.

  1. Explore design alternatives, guidance, and assessment in testing as integral part of design process.
  2. Combat and engineering design/ manufacturing.

1.4 Conclusions

Present (and future) war-fighters have advanced war-winning capabilities based on information-age science and technology. Modelling and simulation tools, products, and capabilities can be advanced by taking into account synergy of modelling and simulation science and technology as well as advances in software engineering and software agents. Here the use of software agents in military modelling and simulation is advocated. Agent-directed simulation offers three categories of possibilities.

agent simulation, agent-based simulation, and agent-supported simulation.

2 WANTED: COMMAND AGENTS, SEARCH AGENTS (S. K. Numrich)

Distributed simulations have provided a new environment for training, virtual prototyping and system-of-systems analysis. Information access and transfer in this new computational environment is an ideal use of intelligent agent technology. In the process of working with the Joint Countermine Operational Simulation (JCOS), we have found at least two areas where the use of intelligent agents can substantially improve the use of the simulation.

JCOS developed near-shore and on-shore countermine components for the DARPA developed simulation now known as JSAF, Joint Semi-Automated Forces. The primary purpose of JCOS was to provide an environment in which the capabilities of novel systems would contribute to the mix of all systems that would be found in the Fleet in the five to seven year time frame. For this reason, it was essential to capture the events of the simulation for evaluation. An After Action Review System, AARS, was developed for that purpose. The initial approach to extracting the data from the simulation was to specify the events that would be of use, mark them during execution and extract them from the logger file upon completion of the exercise. This straight forward approach had both advantages and difficulties. The primary advantage was that it did work and produced the required results. However, as the full logger file was required for processing, no preliminary data was available. Evaluation had to wait until the simulation was completed. Because it recorded all events in the simulation, the logger file was rather large.

The AARS is now being modified to take advantage of intelligent agent technology. The AARS process still begins with the designation of interactions that needed for post-analysis; however, the process of locating and recording the events has now become the task of intelligent agents. There are agents that explore sensor responses, weapon responses (detections and kills or misses), and designated event to event time dealays. While initial JAVA performance was disappointing, consistent effort at improving performance resulted in a system that not only matched the C-code searches, but allowed interim responses to be gathered and displayed.

The AARS system for JSAF is but an initial development in simulation analysis and evaluation that can be facilitated through the use of intelligent agent technology.

The second application is in communicating between simulations and tactical decision systems. One of the most difficult and time-consuming tasks in running a simulation is the development of a scenario. No one but a seasoned simulation developer would ever consider attempting to build a simulation scenario for a simulation of any significant size. However, on a regular basis, duty officers who are not software or simulation professionals create operational plans on tactical decision aids. If these relatively high level plans could be transferred to the simulation and interpreted, a scenario could be developed much more rapidly, perhaps even automatically.

When JCOS was developed, the decision was made to have the events of the simulation, primarily the detection of mines and minefields, displayed on the screen of the decision support system used by the mine warfare community. To accomplish this, the simulation messages were forwarded to a “gateway” that translated from the simulation message type to the Naval message type that would be understood by the decision system. This link with the decision system was relatively simple. Only detection messages were forwarded. The content of the simulation message and Naval message were very much the same – a detection and the location where the detection occurred.

A more interesting, but far more complex transfer of information would be from the planning system to the simulation. The planning system uses a number of algorithms and judgement criteria to determine how a mine hunting or clearance system should be operated. The decision system takes the tasking from superior command, for example, to use available resources to certify that an area is passible.

The problem is how to use the work done in the planning system where you do want the active participation of the experienced human agent to initialize a simulation of that scenario without forcing a specialist to recreate the entire plan from scratch.

There is a term “command agent” that has been used to describe the process of interpreting a message sent from higher command for execution by the next lower level of military command –all within the context of a simulation. It would be very useful to extend that notion to transferring a plan developed on a decision support system into a scenario in a simulation. There are a number of similarities in these two operations. In both cases, the initial information is abbreviated and assumes considerable understanding on the part of the receiver. The receiver has to understand the intent of the sender and translate that message into action.

This notion of translating a plan into a simulation scenario occurred to the JCOS development team; however, constraints of time and resources permitted only the most rudimentary implementation. What we were able to translate from the decision system to the simulation was the overlay of the operational area from the plan. Even that was extremely useful. It saved the simulation developer the time it took to draw these areas on the plan view display.

What one would really like is the ability to take the plan and create the action in the simulation. Unfortunately this process now takes the developer as much as several days and requires a high level of skill in using the simulation. Because there is a considerable emphasis on reasoning and intelligent data collection, software agents appear to offer a promising solution.

To provide a concrete example, consider the case where a planning system develops an optimal approach to pursuing a mission. The plan may provide a selection of vehicles and supplies and perhaps both a map with routes and a schedule. While this information is sufficient for executing a plan, it falls considerably short of what a simulation needs to execute the corresponding scenario. The maps, data, chosen vehicles, supplies and initial schedule must not only be transferred to the simulation system, but must also be interpreted to form the procedural context required by the simulation. For example, the statement in the plan that system X will search operational area A must be translated into a rather large set of procedural commands that move the simulated system X from it's initial location to the search areas, deploy the correct search system in the correct mode, and provide routing information that the kinematic and behavioral models can use. It would seem that the procedural intelligence required might be executed by an intelligent agent.

Time lost between creating the plan and "realizing" it in simulation reduces the utility of the simulation to the non-specialist.

It is worth noting that in many cases, the utility of the simulation is to clarify highly technical events for the non-specialist. Automation through the use of software agents can make the simulation more accessible to the military community and far more cost-effective overall.

3 AGENTS FOR MODELING AND AGENTS FOR TESTING – SOME CHALLENGES

(Adelinde Uhrmacher)

3.1 Introduction

Agent-directed simulation subsumes a variety of approaches. Agents are used as a metaphor for system's modeling, agents are object of evaluation via experimental testing, agents are used as a programming metaphor to facilitate reuse of models and reuse of simulation services and agents use simulation as a method to deliberate about the course of action to take. Thus, the relations between agents and simulation are manifold. In the following, I will sketch some of the challenges a user is faced with if he or she wishes to model a system as a multiagent system and some of the challenges the simulation community is faced with if simulation becomes an integral part in designing multiagent software systems.

3.2 A Challenge for the User

Agents are widely used as a metaphor to model biological, ecological or social systems as multi-agent system. These approaches resign from a monolithic design of macro models as do individual-based or multilevel modeling. Whereas individual-based approaches are typically used for modeling and simulating large homogeneous populations, agent-oriented approaches support more flexible patterns of interaction and behavior. In individual based models typically a stochastic component subsumes the individuals' intentions, desires, and beliefs. Agent-oriented approaches allow to model explicitly mental processes, and thus support a more fine grained cognitive model of decision processes.

These options confront the modeller with a series of problems. What are the results a deliberative model produces that a more abstract mathematical model can't produce, which justifies the use of such a fine-grained model (Conte et al., 1997). How can the assumptions be justified and how can the model be validated (Doran, 1997). The application domain, i.e., the knowledge used for modeling and validating and questions that shall be answered, have to meet the flexibility and expressiveness offered by agent-directed simulation.

3.3 A Challenge for the Simulationist

Testing is an obligatory step of each software engineering process and becomes even more important if the development of a software system must be considered as experimental itself. "At the time of writing, the development of any agent system –however trivial– is essentially a process of experimentation. There are no tried and trusted techniques available to assist the developer" (Wooldridge and Jennings, 1998). Thus, one would assume that experimental testing, which also implies simulation, represents a major research effort in the area of multi-agent systems. However, systematic experiments have not found the expected attention in designing agent architectures. Jennings and his colleagues observe that testing agents is the least developed research area in multi-agent systems (Jennings et al., 1998). Therefore, the discussion of Paul Cohen, Steve Hanks, and Martha Pollack about controlled experimentation, agent design, and associated problems (Hanks et al., 1993) has neither lost its topicality nor its virtue. Testing with predefined dynamic scenarios for competition purposes, e.g. the simulation league of robo cup (Kitano et. al., 1997) has achieved some popularity. However, these tests do not reveal much to predict the behavior of an agent in another concrete dynamic environment.

Therefore, simulation systems are needed which are sufficiently general to model the environment that an agent shall run in and sufficiently specific to allow an easy plug and play, so the agent programmer has not to plunge into the underlying modeling and simulation formalisms.

What are suitable worldviews to improve the acceptance of simulation as an intrinsic part of the agent design process? Agents are characterised by their ability to reflect about themselves and to adapt their own behaviour, composition and interaction pattern accordingly. How are these capabilities best be incorporated into simulation systems? Since we wish to ground simulation systems in formal approaches how can agents and their salient features be reflected in formal approaches to modeling and simulation, e. g. (Uhrmacher 2000). To execute multiple deliberative agents with dynamic patterns of composition and interaction soundly and efficiently, suitable parallel and distributed methods have to be developed since look aheads are hard to define and rollbacks might prove rather costly.

Currently, in all these areas few answers but far more questions exist.

4 KEY CHALLENGES TO AGENT-DIRECTED SIMULATION (Linda F. Wilson)

In my opinion, there are four key challenges to agent-directed simulation.

4.1 Security

This issue is vitally important in the defense community, but it is becoming increasingly important for civilian systems as well. One purpose of using agents in simulation is to facilitate the flow of information. For example, we use software agents to link distributed simulations and data resources. How can we exchange appropriate information while protecting sensitive information? Can we build suitable protection within an open system, or do we need separate systems for true protection? How can we keep information shared with one site from being propagated to another site?

4.2 Standards in Communication

Certain standards exist for the exchange of information between various simulations, and such standards faciliate the comprehension of the exchanged data. However, such standards often require that the simulations be modified extensively (or rewritten completely) to fit the standard. Can we develop automated systems to comprehend different descriptions of the same data, and can such systems find appropriate matches in the data? In short, can we remove the human element while maximizing flexibility in the description and format of the data?

4.3 Computer Resources

As simulation environments become more distributed, who is responsible for providing, managing, and maintaining the needed resources? In the spirit of the World Wide Web, various simulation services can be offered to a large community, and "popular" services may be hard hit with requests. Can software agents be used to distribute the workload?

4.4 System Management and Monitoring

Agent-based systems are often used to automate certain processes, and automated systems must be monitored to keep them from getting out of control. How do we handle resource balancing, fault tolerance, and robustness issues?

5 POSITION STATEMENT (Erol Gelenbe)

We will outline how agent based simulation lends itself to best and worst case evaluation using analytical models. The point will be briefly illustrated via an example in which agents pursue goals in a hostile environment.

REFERENCES

Bradshow, J. ed. 1997. *Software Agents*. AAAI Press.

Conte, R., R. Hegselmann, and P. Terna. 1997. Social simulation – A new disciplinary synthesis. In *Simulating Social Phenomena*, eds., R. Conte, R. Hegselmann, and P. Terna, pages 1-17. Springer, New York.

Doran, J. 1997. From computer simulation to artificial societies. *SCS Transactions on Computer Simulation*, 14(2):69-78.

Finin, T. UMBC agent Web site: http//www.cs.umbc.edu /agents

Hanks, S., M. E. Pollack, and P.R. Cohen. 1993. Benchmarks, test beds, controlled experimentation and the design of agent architectures. *AA/AI*, (Winter):17-42.

Huhn, M. and M. Shing, eds. 1997. *Readings in Agents*. Morgan Kaufman.

Jennings, N.R., K. Sycara, and M. Wooldridge. 1998. A doadmap of agent research and development. In *Autonomous Agents and Multi-Agent Systems*, 1(1):275-306.

Kitano, H., M. Tambe, P. Stone, M. Veloso, S. Coradeschi, E. Osawa, H. Matsubara, I. Noda, and M. Asada. 1997. The robocup synthetic agent challenge. In *International Joint Conference on Artificial Intelligence* IJCAI'97.

Uhrmacher, A.M. 2000 – In Press. A system theoretic approach to constructing test beds for multi-agent systems. In *A Tapestry of Systems and AI-based Modeling & Simulation Theories and Methodologies*: A Tribute to the 60th Birthday of Bernard P. Zeigler, editors, F. Cellier and H. Sarjoughian, Lecture Notes on Computer Science. Springer, New York.

Weiss, G. ed. 1999. *Multi-Agent Systems: A Modern Approach to Distributed Artificial Intelligence*. Cambridge, MA: MIT Press.

Wooldridge, M.J. and N. R. Jennings. 1998. Pitfalls of agent-oriented development. In *Proc. 2nd International Conference on Autonomous Agents* (Agents-98), Minneapolis, 1998.

AUTHOR BIOGRAPHIES

TUNCER ÖREN is a Professor Emeritus of Computer Science (University of Ottawa, Canada) and the Vice Director of the IT Research Institute of the TUBITAK Marmara Research Center in Turkey. He has been active in simulation since 1965. His interest areas include: (1) advancement of the methodology of simulation (including synergy of artificial intelligence techniques such as software agents and understanding, simulation, and system theories); (2) software systems engineering, including high-quality user/system interfaces, computer-aided problem solving environments, and program generators from high-level specifications; and (3) reliability issues of modelling and simulation, software, and AI applications. His recent interest areas include ethics in simulation that he considers as the missing link in VV&A studies as well as the use of simulation in education and training for conflict management and for peace support. He published over 300 documents, and actively contributed in about 280 conferences or seminars held in 26 countries in Europe, Asia, and the Americas. Dr. Ören's email and web addresses are `<tuncer@btae.mam.gov.tr>` and `<http://www.btae.mam.gov.tr/~tuncer>`.

S.K. NUMRICH is a research physicist at the Naval Research Laboratory where she heads the Advanced Information Technology Branch in the Information Technology Division. Research under her direction at NRL includes parallel and distributed processing, collaborative engineering, virtual reality, synthetic environments and decision support technology. She serves as a Program Officer at the Office of Naval Research on a part time basis, directing the development and execution of research into providing consistent synthetic natural environments for distributed simulations. In the international arena, Dr. Numrich serves on Studies, Analysis and Simulation Panel under NATO and chairs the Modeling and Simulation Technical Panel under the Joint Systems and Analysis Group of the Technical Cooperation Program. Her prior research includes underwater sound propagation, fluid structure interactions and modeling. Her email address is `<numrich@ait.nrl.navy.mil>`.

ADELINDE M. UHRMACHER is an Associate Professor in the Department of Computer Science at the University Rostock. Her research interests are artificial intelligence, modeling and simulation, particularly the development of agent-oriented modeling and simulation methods. Dr. Uhrmacher's email and web page addresses are `<lin@informatik.uni-rostock.de>` and `<www.informatik.uni-rostock.de/~lin>`.

LINDA F. WILSON is the Clare Boothe Luce Assistant Professor of Engineering in the Thayer School of Engineering at Dartmouth College. She received her B.S. degree from Duke University and M.S.E. and Ph.D. degrees from the University of Texas at Austin. Her email address is `<linda.f.wilson@dartmouth.edu>`.

EROL GELENBE is a Professor of Computer Science, and the Director of the School of EECS at the University of Central Florida in Orlando. His research is currently funded by NSF, U.S. Army STRICOM, and by several industrial organizations including Lucent, SEO and Giganet Technologies. He has graduated some 60 Ph.D. students who are active in academia and in industry, both in the US and in Europe. A Fellow of the IEEE, his honors include the Grand Prix France Telecom of the French Academy, and the Doctorate Honoris Causa of the University of Rome (Italy). He is an alumnus of the Middle East Technical University in Ankara (Turkey) and is cited in Who's Who in America, Who's Who in France, and Who's Who in Turkey. His email address is `<erol@cs.ucf.edu>`.