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ENTERPRISE SIMULATIONS: THEORETICAL FOUNDATIONS AND A PRACTICAL PERSPECTIVE

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ABSTRACT

Simulating business enterprises is the next major application approach to using simulation technology effectively. Although the term enterprise simulation or something similar is being use with ever-increasing frequency the field lacks a clear definition and discussion of the theoretical basis for what is meant by the term. In this paper I offer my concepts and ideas of how we encapsulate this notion and what theoretical foundations can help us come to a common understanding and eventually help articulate a clear and agreed upon definition of the concept of an enterprise simulation.

1 INTRODUCTION

This paper provides a theoretical basis for the enterprise simulation concept. The term enterprise simulation has recently become more popular, but there is lacking a comprehensive and active discussion about just what is meant by the term. The intent of this paper is to stimulate a discussion on a common meaning. The perspective with which I will start views enterprise simulations in the general sense of a dynamic model or simulation constructed with a top down perspective. Its intended use is to provide an overall conceptual perspective of that enterprise. An enterprise could be a factory, a port facility, transportation network, urban renewal project, entertainment facility, school, military unit or command.

Communality with the use of "enterprise" in the information system field is not unintentional, however we need to understand enterprise simulation as involving more than the information systems or a model of the information flow in the enterprise. We propose to design the salient characteristics of the enterprise simulation so that someone who is familiar with the simulated enterprise will intuitively understand the model outputs at the computer user interface. Enterprise simulations are environments which support decision making and learning. Domains in which enterprise simulations can be or are being used include not only industry, but also the public sector, and the military. In fact, as I will discuss, the concept of enterprise simulation as a more general theoretical perspective for using simulation technology builds from the success of the military in using models to help manage their plans for warfighting. Those concepts can now be applied to a broader range of military activities and expanded to other sectors where resources need to be managed in complex settings.

2 CONCEPTUAL OVERVIEW

Simulating an enterprise means representing in a model that enterprise, its dynamic behavior, and its response to internal and external stimuli. Enterprise simulations must capture a top-down perspective. Conceptually humans build mental models of the complex systems with which they must deal. Examples range from a mental image of the transportation network in their region to how products are developed and move through an office, plant, laboratory, or other facility. Enterprise simulations must seek to capture these mental models for the end user. (Mark 1998)

The purposes that these enterprise simulations serve are also different than the way most simulation technology has been used in the past. Simulations have long been a tool the analyst used to evaluate potential solutions to a management problem they were asked to help solve. The analyst's role in the past has been most often to derive a recommended point solution for management. This is what I call problem-centric simulation. Enterprise simulations are used directly by decision-makers to observe the dynamics of the system as it responds to stimuli introduced by the user or a set of stochastic model inputs. We are notionally eliminating the analyst as a middleman; in actuality the role of the analyst changes from one of developing and running the simulation as a tool to support his or her work to having technical responsibility for developing and validating the models used. Problem oriented modeling and simulation still has its place and continues to be a topic for research into improved methods. It is important that we understand enterprise simulations as a different perspective on and use of simulation technology that may require some unique tools and capabilities (Veek 1999).

3 ENTERPRISE ENVIRONMENTS

Since the systems being modeling are based in the real world they frequently include human elements which interact with either other human elements or other features of the real world or both. A system or organizational perspective is key. Many techniques, such as the IDEF methodologies, have been developed to capture the processes or internal workings of an organization but these are often static representations. There is useful research into adding dynamic behavior to these static representations or using them as input to a methodology or tool that can execute the processes dynamically. (Barjis 1999)

Simulating organizations so that emergent dynamic behavior is evident is needed (Prietula, Carley, and Gasser 1998). Although mathematically based techniques have developed in a variety of domains (e.g., transportation, or urban planning) that claim to capture the emergent behavioral results, they provide users no visibility into the causality of outputs. These types of models are useful for some analytic purposes but frequently are not adequately scalable nor are their results easily explained to managers and decision–makers. We need a different conceptual perspective and technical approach to capture the enterprise to be simulated.

Systems that lend themselves to an enterprise perspective are frequently a collection of entities, some existing in nature but many artifacts created by man, interacting with one another within an environment. The real world entities together with the real environment within which they interact comprise a system. Most often this is a complex system that has emergent behavioral properties (Casti 1996). Simulations emulating such complex systems have to be designed to accurately represent both the effects of the environment and the behavior of individual entities. This may suggest that an object-oriented simulation will be best but that conclusion is a technical decision based on many factors and it is best to keep in mind that non-deterministic mathematical models are sometimes appropriate.

One can also see that capturing the behavior of each entity in the system is a modeling problem in and of itself. In this case the enterprise simulation is most easily viewed as the aggregation of the behaviors as the models which make up the enterprise interact with one another and the environment. These objects or models all interact within a synthetic representation of the real world environment that defines the context of the enterprise.

There are many examples of dynamic systems that could benefit from the enterprise simulation perspective, let us consider two of them. Traffic engineers have used models of traffic flow for several decades. These are analytic tools which help design the features (e.g., an interchange off of a limited access roadway) of a transportation network. They model and simulate traffic in parts of but not all of the system. The emergent behavior of the overall traffic network in an urban area is only obvious when the vehicles (entities) are allowed to *behave* individually and impact the overall stability of that entire system (see discussion of Washington D.C. area 2 June 1999 incident below).

The military already uses this conceptual approach in their wargaming simulations. They are interested when training their commanders and experimenting with possible battle plans in the overall outcome from the collection of entities that comprise the forces on the battlefield. Wargaming, as practiced by the military with computer supported models, is really the precursor of the enterprise-modeling concept. Wargames are contexts in which to practice procedures and think about ways to conduct an operation; they do not fully test a given operational plan or validate a single optimal course of action. The inherent uncertainty of combat leads to approaching operational scenarios from a perspective of enterprise simulation. Indeed the military has been doing this for the better part of a decade. The same approaches can support business and the public sector in planning and strategizing for the future.

4 CHARACTERIZING ENTERPRISE SIMULATION

There are several ways to characterize enterprise simulations. Some support multiple uses. A common characteristic in the types of enterprise simulations that we have developed is that they support human decision-making. They directly support the decision-maker who is the end user, resulting in decisions that are either easier to make or better informed (Mielke 1999). I am not suggesting that enterprise simulations are some type experts that claim ability to arrive at an informed decision by alone. Simulating an enterprise means building a decision support tool, not a solution generator.

There are unique features for the underlying systems which lend themselves most readily to enterprise simulation and which will benefit the most from our approach. We are interested in complex, dynamic systems. Many of them are *marginally stable complex systems* in that they operate in a stable state, however unpredictable events or perturbations can place them into a non-stable state. For the purpose of supporting the decision-makers, the actual event that causes instability is not as important as the way in which those controlling the system (managing where appropriate) respond to the instability. The reason for this is that the destabilizing events are highly unpredictable; therefore preventing such events a priori to maintain stability is not always feasible.

An example of this was the traffic system breakdown in Washington D.C. on 2 June 1999. The overturning of a semi tracker-trailer carrying black powder explosive near a critical intersection of main arterials at 4:00 am

caused essentially a complete breakdown on the system. Traffic throughout the capital region was affected for 24 hours. Officials responsible for managing traffic could neither have predicted nor probably even responded to the actual incident differently. The traffic network in this region is marginally stable in that this single incident caused the entire system to breakdown to the point of almost failing to serve its intended function – moving vehicles throughout the system within a reasonable amount of time.

Complex dynamic, real world systems contain entity level elements, for example, people, vehicles, ships, manufactured goods in a supply chain, products in a retail system and etc. These entities collectively (cooperatively, individually or sometimes competing with one another) interact in their real world environment according to specified or accepted rules of behavior. The individual behaviors of entities are important, but of greater interest to those with overall responsibility for the system or enterprise is the aggregate interaction of entities that determine system-wide behavior or dynamics. Dynamic systems of interest are those which are manageable (at some level) or for which the ability to understand or predict their behavior is of value to the simulation user (financial markets for example).

5 SIMULATION IS NOT THE ANSWER TO ONE SIZE TO FIT ALL PROBLEMS

A word of caution is warranted because as simulation has become more popular, it is not uncommon to find it being touted as the best solution for all system modeling problems. This is a dangerous trend because highly stable systems should yield to a mathematical-based deterministic representation, and executing those models should generate predictions of their output. In the past attempts were sometimes made to capture the behavior of complex dynamic and unpredictable systems with weak deterministic mathematical model because these were the only tools available. In the military domain combat attrition models fall into this category. Many transportation models are also built using this approach and they work well in the small, predicting queues at intersections, traffic flow through an interchange and etc. but are not scalable to system level modeling a city wide transportation network.

Today we are in danger of coming full circle because some modelers and analyst tout the use of non-deterministic approaches to simulate all real world systems; even those which lend themselves to closed form management science techniques. An example of this is modeling a transportation-distribution problem where there exists a defined network, resource set and fixed constraints, like product warehousing and distribution to end use sites.

6 APPLICABLE SOFTWARE CONCEPTS TO SUPPORT ENTERPRISE SIMULATION

It is instructive to consider what computer software technology is applicable when developing enterprise simulations. This list is not intended to be comprehensive but rather suggestive, as this area needs significant new research and experimentation.

- Object-oriented representations lend themselves very nicely to support building an enterprise simulation. The reason is that we want to provide a perspective on the enterprise in the model that will convince the viewer that

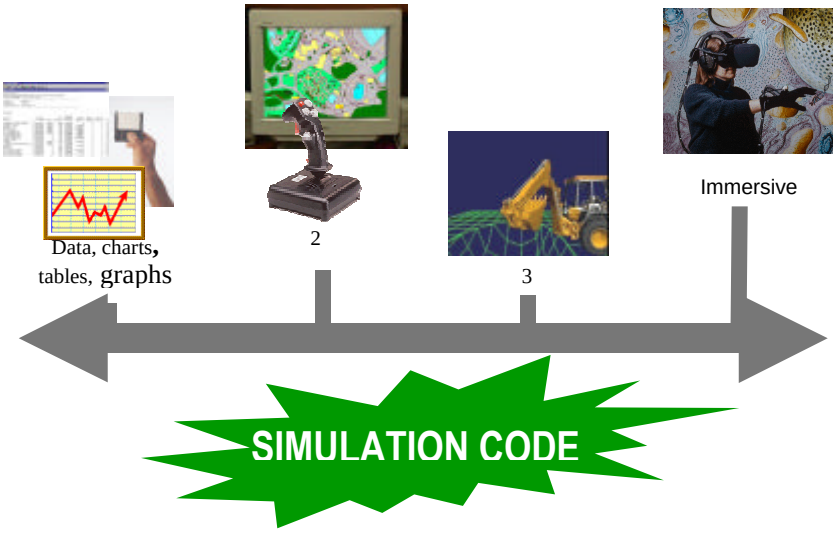

Figure 1: Simulation Interface Technologies

- It is a reasonable representation of their domain. The ability to view changes of the system in terms of impacts on entities and their associated behavior makes the results both more acceptable and easier to validate.
- Visualization may be an appropriate type of interface to the dynamic model. Because we are interested in the overall system dynamics, frequently it is useful for the user to be able to see the system dynamically change or to easily see the results of state changes. The simulation is not just the visual output seen at the user interface; the user interface is merely a way to display the dynamic behavior captured in algorithms within the models or in the object methods. The results of an enterprise simulation can be displayed using any of the interface technology shown on the continuum below; it is a question of appropriateness to the task and cost for development.

7 THE PRAGMATICS OS USING ENTERPRISE SIMULATIONS

A discussion of enterprise simulation needs to include some perspective on why to use it and when to use it to help us understand the context and purpose as well as provide insight into selecting appropriate technical approaches. Enterprise simulation is in fact different than the traditional OR/SA perspective which views simulation as a tool used to help generate a solution space for a problem. Enterprise simulations are decision-support environments that allow users to reflect on and improve on their own expertise and understanding about the enterprise. Therefore the reasons for using them almost all support or derive from this foundational principle – use enterprise simulation to enrich understanding and knowledge.

Enterprise simulation always should be developed to support the user's conceptual understanding of the domain and enterprise itself. This is key because such a simulation tool, if effective, can support decision-making processes, facilitate learning, and provides a training environment. Whether an enterprise simulation is used to contemplate decisions or to support explanation it is a good context for capturing expertise.

A cognitive viewpoint is that the results of the enterprise simulation as presented to the user through one of the interface techniques shown in figure 1, represent an externalization of a mental model of that enterprise. This mental model should replicate how the domain expert who helps construct the simulation conceptualizes the enterprise, but ideally it will be suitable for sharing. A shared mental model is a topic of interest to cognitive scientists in general. Users can share this representation during discussions about the enterprise, teach it to others who want to learn about the environment, and even use it to capture their own experiential knowledge within the definition of the synthetic environment, algorithms or object methods.

Appropriately constructed enterprise simulation allow users to focus on key features of the system. They are not implemented as black box models with only inputs and outputs visible to the user. The details may be important; it is up to the user of the simulation to determine that and not the developer. As we discussed earlier, the simulation users are most often interested in seeing is one they can use to determine what causes a failure in the system so they can plan reactive strategies and evaluate them. Plans themselves can be tested using enterprise simulations.

8 IMPLICATIONS AND SUMMARY

We are convinced that bringing simulation to the desktop of decision makers by providing them a model of either their entire business enterprise or some critical complex sub system within that enterprise, is the approach that will stimulate interest in and further the state of the art for modeling and simulation technology. Tools exist today which, using current hardware, or what will be reasonably available in the next several years, can provide realistic two and three-dimensional interfaces that capture the dynamics of most enterprises. While 3-D perspectives appear attractive we find that many managers are quite satisfied with an intuitive and appealing two-dimensional view. The more significant challenge will be collecting and storing the data necessary to drive these simulations. However, this is not a process which has to start from scratch, most large organizations have been using automated data management systems for nearly a decade. Data mining tools and concepts afford the opportunity to extract the required data to drive enterprise simulation models using existing databases, flat files and archived records.

Modeling and simulating a business enterprise will not be the only future use of simulation and visualization technology, but we believe it is key to wide spread acceptance in the commercial sector. The use of simulation for training was the key application which converted the military community wholesale into strong proponents and user of modeling and simulation in applications now ranging from operational planning to procurement to logistics management. Commercial industry also needs a key application area to catalyze them to embark on a similar cultural change to more readily embrace and apply modeling and simulation. We believe that the near term ability of enterprise simulation to support decision making and strategic planning and to impact corporate bottom line performance make it that key application in the commercial world.

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THOMAS W. MASTAGLIO was appointed Executive Director of Old Dominion University's Virginia Modeling, Analysis and Simulation Center and Research Professor in Electrical and Computer Engineering in 1996. Dr. Mastaglio is a 1969 graduate of the U.S. Military Academy. He retired from the Army in 1991 and worked in the defense industry as a senior engineer, program manager, and scientist. He was a key leader on both the Close Combat Tactical Trainer and Warfighter Simulation 2000 integrated development teams with IBM and Lockheed Martin. Dr. Mastaglio earned a Doctor of Philosophy degree from the University of Colorado in Computer and Cognitive Science in 1990. His research interests include the application of artificial intelligence to improving human-computer interaction and learning, usability engineering, cognitive modeling, the development of large-scale enterprise models and simulations, and educational requirements for modeling and simulation. Dr. Mastaglio has served as a member of the Army Science Board and a technology consultant to the Department of Defense.