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Session V: Present Trends in Military Operations Research

Karl A. Bertsche

Information and Communication Systems
Dornier GmbH
Friedrichshafen, Germany.
e-mail: bertsche.karl@dornier.dasa.de

Mr. Bertsche is a project leader and is presently completing a study for the German army engineers considering explosive demolition in a Peace-Keeping Mission in the military OR-Section of Dornier (a company of DaimlerChrysler-Aerospace). He has written object oriented Programs concerning minefield effectiveness, and an analysis tool for the sustainability of German forces. He has also programmed an object oriented dynamic model of Infantry Combat. He was previously a nuclear engineer at Babcock & Wilcox in Virginia, U.S.A. He has a Masters of Engineering degree in nuclear engineering from New York University.

ABSTRACT

This paper gives an overview of the present trends of Simulation in the area of military operations research (OR). Even though these observations have been made for the German military, similar trends can also be seen in the OR development of the United States military. These development trends are in the area of distributed simulation, computer generated scenarios/forces and three dimensional simulation. These trends will influence the methods used for OR analysis in the future with respect to training, analysis and decision support tools.

INTRODUCTION

The objective here is to present the present trends of Simulation in the area of military operation research and discuss the significance of these trends. Presently, the trends of OR Simulation are concentrating in the following areas:

- Distributed Simulations.
- Computer generated forces and scenarios.
- Three dimensional simulation models with high level of detail.

The above areas of simulation are important to the German military (the army in particular) because of varied missions and tasks which they may encounter today and in the future as Germany has increased its international presence in peace enforcement operations .

Only through the enormous advances in computer technology and new programming methods has it been possible to generate simulation models, which are capable of analyzing such complex issues facing the military of today.

DISTRIBUTED SIMULATION

A major topic of present military OR-Simulation is the area of distributed simulations. The term distributed simulations refers to the interaction of two or more independent simulation models on different computer systems operating within a single scenario. The necessary communication between the simulation models is achieved via a local area network (LAN) or a wide area network (WAN) or an Internet Connection. At present there are two different communication methods which are being employed for distributed simulations systema one being Distributed Interactive Simulation (DIS) as described in reference[1] and the other being High Level Architecture (HLA) as described in reference.[2]

Both systems of communication allow the results of simulation to be transferred from one system to another systems and visa versa in real-time. The results of each time step serve as partial input boundary conditions to each of the simulations participating within the scenario. The main advantage of distributed simulation is that two or more computers are generating results in parallel and that the results of each time step influence the other participating simulation models within the scenario. The level of distributed simulation is only dependent on the availability simulation models and the level of detail of each model. This indicates, that each side (friendly and enemy forces) may each consist of several distributed simulation models, where each model may be representing a different branch of the armed forces or even a particular type of force within a certain branch (i. e. army engineer-, armored-, artillery and infantry forces). The level of detail may go down as far as a single system. As one might suspect, the speed of simulation is appreciably increased due to this parallel processing method via network. A brief summary of these communication methods (DIS and HLA) is given below.

DIS interfaces with the real-time software packages commonly used in war game environments and links individuals at various sites by connecting them with the Distributed Simulation Internet (DSI). As a result, users can create and share a virtual battlefield for interactive simulations. DIS brings space analysis capabilities too. These guidelines govern communication services and profiles, application protocols, and other elements for all members of the DIS environment. DIS provides users with a peer-to-peer connectivity capability that is suited to a variety of data-exchange purposes, such as military exercises. DIS uses the DSI to read Protocol Data Units (PDUs), which are then filtered and translated into familiar objects - such as satellites, aircraft, missiles, ground vehicles, or ships - that are contained in the shared scenario. The object data is updated upon receipt of the PDU, ensuring a scenario that provides complete and accurate information. These scenarios provide an environment to centralize manned simulators, semi-autonomous forces, and live, instrumented equipment communicating over the DSI.

DIS processes the input of the entity-state PDU from the DSI to determine the object class and its location. When the DIS module is engaged, it listens to the DSI for PDU data. When a PDU is received, the PDU is decoded and filtered based on its entity-state data (position, attitude, algorithmic parameters, kind, domain, or country, etc.) and the DIS module properties in effect. PDUs may be translated into objects such as tanks, trucks, missiles, aircraft, or ships.

Once an object is created, the position and attitude for each is updated as a new Entity State PDU data is received. DIS allows the user to specify the amount of historical data retained, and provides playback capabilities that allow the user to review all saved data. DIS employs a unique method to generate PDUs for all typed objects. The user enters the relevant Entity State information for an object and this DIS method produces an accurate Entity State dead-reckoning PDUs. This mechanism allows the broadcasting of object states to DIS simulations and users over the DSI.

One disadvantage of the DIS communication system is the vast number of PDUs which must be broadcast on the DSI revealing the object states for the participating Simulation models. Depending on the level of simulation detail and the scope of the scenario the DSI may become overloaded. If DIS communication is chosen, the DSI network must be well defined and the broadcasting of information must to be limited to the DSI network. Otherwise the performance of other LANs and WANs can be significantly impaired by the flood of PDUs generated by the simulation models. Recognizing the shortcomings of DIS the US Department of Defense is developing another method of communication for simulation models.

This new method of connecting distributed Simulation models (to one another is the implementation of the so called “High Level Architecture” (HLA). The architecture is defined by the following features [3]:

1. Rules which govern the behavior of the overall distributed simulation called the Federation and their members called the Federates.[4]

2. An interface specification, which prescribes the interface between each federate and the Runtime Infrastructure (RTI), which provides communication and coordination services to the federates. Federation communication only takes place between each federate and the RTI, not between federates themselves. The RTI as the central coordination software component as well as the federates can be located on any network computer on the simulation Network or Internet.[5]

3. An Object Model Template (OMT) which defines the way how federations and federates have to be documented (using the Federation Object Model, FOM and the Simulation Object Model, SOM, respectively). The OMT uses a tabular approach which is well suited for automated tools and conversion into the OMT data interchange format (OMT DIF). OMTs promote the reuse of single federates or federations as a whole. Federations can be viewed as a

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> contract between federates on how a common federation execution is intended to be run.[6]

The time management services provided by HLA allow the transparent running of federates under different time regimes (e.g. real time, time stepped, event driven). [7] This development originated from military application side and its architecture seems also to be well suited for civilian types of applications.

The requirements imposed on the simulation and animation tools by the HLA are considerable, which may be one of the main reasons for the fact that most of the example simulations released up to now were written in C++. Therefore, a closer look at the connection between classical simulation tools and the High Level Architecture seems to be necessary.

The development of HLA has just begun in the past few years and still needs further development. HLA is already considered to be the most flexible method for data exchange of complex simulations models.

With distributed Simulation Models (DIS, HLA) the users can develop tactics by playing not only against computer models but by playing against the tactics of other individuals employing certain simulation models for a particular scenario. The primary purpose of distributed simulation lies in the area of training and analysis. The Simulation is usually performed interactively allowing the users to make online changes during the simulation.

COMPUTER GENERATED FORCES AND SCENARIOS

One major effort of any simulation is the compilation of input data. This is true for military OR simulations (in particular for combat simulations), which consists of an extremely large heterogeneous data sets. The German armed forces are presently investigating the possibility of developing a force and scenario generator in order to appreciably reduce the required time to generate the input data for scenarios. [8] To develop such a scenario generator, one must first determine the data which is required, as well as the format, accessibility and validity of the data. Preliminary results show that the following input data sets are essential for military OR simulations:

- Environmental data.
- Force structure data.
- Systems data.
- Timeline of events.

The environmental data can be broken down into meteorological and geographical data. The meteorological parameters considered in simulations are: isobars, air temperature, relative humidity, air pressure (see level), wind direction, wind shear, amount of precipitation, kind of precipitation, lower cloud ceiling, upper cloud ceiling, type of cloud

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cover, cloud density, Frost elevation, degree of turbulence and ground moisture. These are just some of the important input parameters required by flight and artillery trajectory simulation models. For the scenario generators a given set of default parameters would appear in the corresponding input dialogs. These Parameters can easily be changed by accessing the appropriate input fields and altering the displayed data.

In addition to the meteorological data, the geographic information is required to generate the military maps showing the present military situation. In order for the scenario generator to produce a map, the following geographic data sets are required:

- Raster data (elevation model digital terrain elevation data, DTED).
- Vector data (i.e. roads, rivers, cities, forests; via the digital feature analysis data, DFAD).
- Picture data (for possible corrections of both existing DTED and DFAD data sets).

The DTED and DFAD data are available on CDs and are kept up-to-date through the Military Office of Geography.

Another important part of the scenario generator is the force structure generator. With this separate tool the user should have the possibility:

- To generate force structures for all force and institutions.
- The entities of the military structure are linked to characteristic data and systems data.
- The entities of the military structure can be graphically displayed and dropped on the military map.

The generated force structures can be implemented for training, decision support, operations support and other OR analyses. By dropping the tactical symbol on to the military map, the structure generator also supplies the associated system data for the simulation. The force generator will not only represent own forces but will also be capable to generate force structures for enemy, neutral and friendly forces, by using the ‘drag & drop’ techniques. The forces can be placed any where on the maps surface allowing the user to generate any military situation he requires.

In order retain a certain flexibility, the structure generator should have the following basic characteristics:

- The top level of command for a simulation can be freely selected by the user.
- Command components must be represented.
- Subordination can be chosen freely.

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- Ties to logistic support are identified.
- Communication ties can also be chosen freely.
- Institutions are to be defined for Simulation and operational support analysis.

The German military forces have their force structure data in several databanks. The data access to these Databanks has already been verified in other OR studies. Sources of force structures of enemy neutral and friendly forces have been identified. But the identified structures are only available for command levels higher than battalion level. For lower levels of command assumptions about the force structure will be made. As a starting point the force structure of the enemy, neutral and friendly forces at lower levels of command are assumed identical to our own forces structure. The force structure generator allows correction to be made if detailed knowledge about the lower command level becomes available.

Data of implemented systems should also be included in the scenario generator. No single Databank was found acceptable which contains validated system data. Therefore suggestions were made, how data of various systems could be integrated into a relational type of databank. In order to keep the number of descriptive aspects of a system to a minimum, requires that the systems be divided into a number of subsystems. Every subsystem has it's own limited number of descriptive aspects, which will be recorded. A system is then described through its number of subsystems including a smaller number of descriptive aspects necessary to describe the system as a whole.

In addition of dropping forces to the map surface of the scenario generator, work is required before the scenario generator has all the necessary data information to satisfy a particular simulation model: This work contains the following:

- Generating the military situation.
- Generating time schedules translation paths and velocities for the Objects.
- Correlate Actions and Commands.

The Analysis of the simulation models showed, that format and structure of the action plans are inconsistent among the simulation models. This has as a consequence, that every simulation model must be adjusted to meet a particular agreed-upon standard.

Basically, the positioning of objects on the map can either be performed mechanically or by assigning UTM–coordinates to the elements. The force structure elements can be placed via drag & drop any where on the surface of the displayed map. Actions, commands and schedules are to be placed in a temporary Databank Model. The simulation model will use this information to carry out the simulation of a scenario.

The demand for such a scenario generator is steadily increasing, because the models are becoming much more complex with regard to force structure, geography, system data, environmental conditions and C4I.

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3-DIMENSIONAL SIMULATION MODELS WITH HIGH LEVEL OF DETAIL

Another major area of interest in military operation research has been the development of three-dimensional models. This class of models have been developed primarily in the area of training of very expensive and technically complex weapon systems (i. e. aircraft, ships, tanks and even trucks). Depending on the realism achieved by different models, the trainee is capable of getting valuable operator training primarily physical insights on a particular system. The 3-D realism is achieved by projecting different pictures of an artificial environment onto screens in front of the windshield and in front of the side windows of the simulated weapon system(i. e. aircraft cockpits and truck cabin). To achieve the necessary training, the operator cabin mock-ups are a one-to-one representation based on dimensions, instrumentation and controls of the actual system. These training simulators appreciably reduce the required operating time, which would have been required on an actual system. Consequential benefits are less wear–and–tear on the actual system hardware and lower accident and fatalities rates during the total training phase.

3-D Simulations are also progressing into the field of OR analysis.[9] Three dimensional models can be used not only for training purposes but also for analysis. One example is the loading of a transport aircraft, [10] railroad cars and ships. With such 3-D simulation tools, it is possible to give analysts insights to very complex spatial problems which are not evident in a 2-D simulations. A typical example of such a problem is the loading of a military transport aircraft with military vehicles. In such a model structural interference between the military vehicle and the internal structure of the aircraft are graphically displayed and areas of interference can be identified. Such a 3-D Simulation model can also be used as an analysis tool to determine the proper angle of incline for loading ramps for a transport aircraft or it may lead to design changes of the cargo entrance area. In addition an optimization model may be developed in the future to optimize the use of the cargo space.

Another area where 3-D simulation is being implemented, is the simulation of the dismounted soldiers in different types of terrain (urban and wooded areas). The main purpose of such models is to simulate combat situations using such basic functions as seeing, walking, running, creeping, aiming and firing of weapons, throwing of hand grenades in various types of terrain (urban and wooded areas). With a 3 dimensional view of objects like soldiers, buildings, trenches, ditches, embankments, trees and shrubs additional information about the objects position are conveyed to the user (i. e. distance). A stand-off view (top-, front-, side- and back view) can be taken or the vision through the eyes of each individual soldier can be obtained. With this type of simulation, tactics of the attacker as well as that of the defender can be analyzed. In addition analysis of weapon effectiveness will be an area of further analysis.

Another significant area of interest, within the 3-D combat simulation is that of visualization of the surroundings. An important parameter is the generation of perspective vision of the objects (reduced size at a further distance) but also the construction of the surrounding terrain. This includes the construction of various tree types, bushes, trenches, ditches, embankments, houses and fortifications including changes in elevation just to mention a few types. Other parameters such day, night, dawn, dusk and artificial light sources as well as fog and smoke can be simulated. Basic lighting conditions (light sources) and

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intensity are input parameters to the simulation model, which will generate the amount of light present at different location points in the simulation model.

Another major effort is to generate a data bank, where large number of constructed objects can be chosen. This should simplify the generation of terrain data for a scenario. Here the Internet is a significant source where such constructed objects like houses, office buildings (multi story buildings) and factories are offered. Three dimensional objects are usually saved under the WRML standard format. Not only is the basic constructed object of interest, but the influence of combat actions on the structure of the object are also required. Such combat consequences would be perforated walls, partially collapsed buildings, bomb craters, felled trees through explosive charges. These simulated changes in the surrounding terrain are called “dynamic terrain” and they influence the mobility of the infantry soldier as well as different vehicles.

There are two separate approaches used in 3-D simulation methods. One relies on an interactive method, which is installed on one workstations or on high-end PCs. In such a simulation each individual soldier is set in motion by the analyst using predefined functions. He has also the possibility to develop an entire scenario and plans the actions of both the attacking and defending soldiers. In order to keep the analysis time reasonable (1.5 to 2 hours for 1 scenario) the number of object soldiers must be limited to 2 or 3 squads which includes the enemy forces. For a lager simulated force structure the simulation performance rapidly decreases and makes the required changes for each object much more difficult. Another approach is the use of distributed simulation whereby the motions of a groups of combatants within the simulation model are controlled by individuals each operating a separate work station or a PC. In the future the information exchange will most probably use HLA to inform the different participants (federates) of locations and detection of objects. Information such as friend or foe, location and distance will be some of the parameters transmitted to the scenario participants.

One major problem in the past and the present is the simulation of body motion like walking, running, falling, squatting and all the transitional modes. In the past, the generated image of these soldiers were relatively simple (consisting a very limited amounts of polygons) which gave the impression of a ‘Play–Mobil’ type of ‘toy’ soldier. The simulated motions were usually very abrupt and choppy. Through significant advances in computer technology (CPU Speed, main memory and separate graphic card processors and graphic card memory) and by increasing the number of polygons more realism of motion of the soldier has been achieved. One example of such a simulated soldier is the DI-Guy from Boston Dynamics.[11]

In conclusion three dimensional simulation is primarily used in the area of training operators of very expensive and technically complex weapon systems. Successful applications of 3-D models have been used, to analyze the loading of military cargo airplanes with bulky air cargo. A more recent trend in 3-D simulation application has been the simulation of the dismounted soldier in different geographical locations and environmental conditions.

SUMMARY

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These three major areas of simulation development (distributed simulation, computer generated forces and scenarios and 3-D simulations) should not only be seen as three separate themes of OR development, but can also be viewed as an effort which may lead to an integration of these development into one major high resolution simulation model. Such a high resolution model can only be managed with a fully automated scenario generator, which will not only generate the basic terrain but will also construct the major features of urban and surrounding areas. Due to the vast numbers of objects which are required in a large scale scenario, the simulation models will most likely be distributed over many computers connected by high speed networks in order to execute the models in parallel. This parallel processing not only expedites the execution of the scenario but also simulates the real world more accurately.

Significant hardware as well as software developments are still needed to produce such large scale high resolution simulation models. These simulation models will not only be capable of simulating soldiers, weapons and weapon control systems but may possibly simulate in the future population, economic, political and cultural behavior in various societies under various stress conditions. For such simulations, the required software would require the use modeling and analysis techniques which have already been demonstrated in models like DEXES.[12] Other approaches could use artificial intelligence and related methods

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