ПІДГОТОВКА ВІЙСЬКОВИХ ФАХІВЦІВ

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M. Yakovlev, O. Sovhar, Y. Ryzhov

Army Academy named after hetman Petro Sahaidachnyi

DISTRIBUTED INTERACTIVE SIMULATION TECHNOLOGY ITS APPLICATION IN COMBAT SIMULATION

The article briefs the characteristics, architecture, key technology of distributed interactive simulation, in armed forces. It explores the application of distributed interactive simulation technology in army combat simulation, and brings forwards the basic concept of realizing combat simulation of army forces with distributed interactive systems.

Keywords: *Distributed Interactive Simulation; Combat Simulation*

Introduction

Problem statement

The use of simulators in military training is not a new idea - sand tables have been used for centuries for planning battles. Recent advances in computing capability, communications, and computer image generation (exemplified by the Internet and the World Wide Web), together with lower acquisition and operating costs, have resulted in the emergence of distributed interactive simulation (DIS). DIS provides the ability to link many simulators - regardless of location — and allows them to operate together in real time as if the participants were in the same location.

To date, the primary focus of research in distributed simulation-based training has been the continuous quest for greater realism in visual displays; enhanced fidelity of the models that drive the simulation; and the need to improve the speed, reliability, and capacity of communications among different simulators and trainers. Less effort has been devoted to developing technologies that can increase the instructional value of a simulation exercise or that could help an instructional designer make the best use of a simulation-based training opportunity. Such technologies would help an instructor to design more effective scenarios; more accurately and efficiently observe, record, and analyze the trainees' performance; and support the necessary learning events before, during, and after the scenario to meet specific training objectives [1].

Objective formulation

The article is aimed at providing an insight into the concept of distributed interactive simulation, examining rationale for application of distributed interactive simulation in combat training of Ukrainian Armed Forces and analyzing its value as training tool in cadets' preparation.

Main part

Definition of Distributed simulation. Distributed simulation (DIS) is a technology that enables a simulation program to be executed on distributed computer systems [2]. There can be many reasons and objectives for using distributed simulation. They include the desire to obtain s*peed-up* (i.e. a reduction in the execution time of the simulation) as well as the need to couple heterogeneous and possibly geographically distributed simulation components. The early success of the distributed interactive simulation (DIS) protocol in enabling distributed simulation has been overshadowed in recent years by the complexity of interoperability protocols such as the High Level Architecture (HLA). The increasing complexity and associated cost of distributed simulation are acting as barriers to development, and consequently as barriers to widespread use of distributed simulation outside the military domain. Improved realism and more effective after action review are among the benefits of a computer-simulated scenario. The military is proverbially accused of always training for the last war. To avoid this predicament, the military make extensive use of simulators, simulations, and exercises, designed to emulate present or projected conditions. Models and simulations are used for several important purposes:

- training (to maintain readiness),
- analysis (of the effects of proposed tactics or system acquisitions),
- planning and rehearsal of operations,
- demonstration of new technologies.

A distributed interactive simulation is "distributed" in the sense that simulator computers at by means of a local-area network (LAN), which in turn maybe connected to a wide area network (WAN) such as the Defense Simulation Internet (DSI). Trainees can enter disparate tank, helicopter, or other simulators and all participate in the same simulated combat. The simulation is "interactive" in the sense that humans interact with the computers to influence the simulation. The battle does not follow a set script, and trainees win or lose on the basis of their performance. The trainees fight a similarly networked opposing force, which maybe a combination of *virtual* forces-real people operating simulators - and semiautomated forces (SAF) - vehicles and weapons simulated by computers with humans providing operational supervision. In both the virtual forces and the semiautomated forces, human behavior is simulated by humans, albeit humans not affected by the many stresses of real combat. These simulations hold promise beyond their capability to train equipment operators to work as a team. Ever larger numbers of networked tanks, airplanes, and other platforms allow higher echelon commanders to plan operations and conduct them in simulation before conducting them in combat. Proposed weapon systems can also be simulated in order to evaluate and, if necessary, redesign them - before the first unit is built.

The key DIS design principles are:

1. There is no central computer that maintains absolute truth and tells each simulator how its actions influence others.

2. Each simulator, with its own computer, transmits the truth about its state, movements, and actions. Receiving simulators determine whether that information is relevant to them and, if so, what effect it has on them.

3. Information about non-changing objects (e.g., terrain) is known by all simulators and therefore is not transmitted between simulators. Each simulator broadcasts its unique state, movements, and actions to all other simulators using standard Protocol Data Units (PDUs).

4. Each simulator calculates or "dead-reckons" the positions of all other simulators in its vicinity. Each simulator also maintains a dead-reckoning model of itself and regularly compares its actual state with the dead-reckoned model. Whenever a significant difference exists between the actual and dead reckoned states, the simulator broadcasts state-update information.

Simulators, such as the Link Trainer, have been used primarily for training and mission rehearsal. More abstract simulations and models have been used for analysis and operations planning. Advances in the technologies of microelectronics, computer networking, and computer graphics have led to supercomputers, the Internet, and synthetic environments for virtual reality (VR) [3]. They have also made possible a new kind of military training, pioneered by the Defense Advanced Research Projects Agency (DARPA - now ARPA1) in its Simulation Network (SIMNET) program, which began in 1983. SIMNET began as a Tank Team Gunnery Trainer to replace existing tank simulators. Through adroit use of increasingly capable and economical computer equipment, SIMNET's developers expanded their system from a tank simulator to a tank battle simulator for company-sized units. Multiple interconnected tank trainers maneuvered on the same imaginary battlefield and cooperated to engage a common enemy. Their crews sat inside tank like boxes and viewed the imaginary battlefield through television screens mounted where the vision ports would normally be. DARPA's SIMNET program ended in 1989,but the simulators, communications protocols, and network developed by the program are still being used and upgraded by ARPA's Advanced Distributed Simulation (ADS) program, the Army's Battlefield Distributed Simulation-Developmental (BDS-D) program, and other Department of Defense (DoD) programs. The term is still applied to simulators, networks, and simulations that still use the SIMNET communications protocols, which have been superseded by the Distributed Interactive Simulation (DIS) protocols.

Terrain Database Construction. Battlefield interaction takes place on complex terrain, and the virtual terrain of a synthetic environment should reflect its important features. A tank commander's view of the battlefield is very different from that of a pilot, and tank commander's requirements for detail in terrain representation are different [4]. Having a full field of view is critical for pilots; providing it requires a terrain database and a means of rendering and displaying the scene that the pilot would see, whatever the direction of his gaze. A tank driver, on the other hand, needs only the restricted field of view provided by his vision block; however, his tank simulator needs to know soil properties that affect traction. Ideally, the behavior of the soil should also be simulated. For example, if wet or sandy, the soil should develop ruts if many tracked vehicles traverse it. A significant indirect cost of the use of computer image generation is the digitization of terrain data for use as terrain databases. Those databases contain all the information about a piece of land necessary for the computer to project hills, trees, and other features combatants would need to see. A terrain database describing Fort Hunter Liggett, California, has been widely used for DIS demonstrations because of its availability and detail. Remotely sensed data, unlike ground survey data, provides multidimensional views of terrain using multispectral scanners, infrared cameras, imaging radars, and photography. Another revolution has been in the direct use of digital terrain. The ultimate product of cartographic data need not necessarily be a paper map. The raw electronic digital cartographic information can be directly used and imbedded within other systems. Direct digitalization of military operations including telephone poles is used for navigation and routing, but for many uses a map is more informative than any picture could be. Three-dimensional terrain databases have been generated from photographs in two weeks using four weeks of manpower. Overhead imagery can be turned into three-dimensional scenes showing key buildings, topography, and important features power lines, and roads. Digital information on troubled areas is increasing, and techniques for direct use of remotely sensed data are improving. The final step will be to learn to feed that information directly into targeting weapon systems. Challenges for terrain database generation include the need to combine data collected by a variety of sensors and stored on various media in Simulation Architecture.

Simulation Architecture. The US Department of Defense's draft Modeling and Simulation Master Plan defines *architecture* as "the structure of components in a program [or] system, their interrelationships, and principles and guidelines governing their design and evolution over time" [1]. It calls for the development of a comprehensive, abstract *high-level architecture* for military simulation: "the major functional elements, interfaces, and design rules, pertaining as feasible to all military simulation applications, and providing a common framework within which specific system architectures can be defined". The current, still evolving DIS architecture evolved from that of SIMNET. Each simulator would be designed to do its own simulation processing and image generation. Each simulator is a self-contained unit, with its own host microprocessor, terrain database, display and sound systems, cockpit controls, and network interface. Each would generate all the sights and sounds necessary to train its crew. Each tank crew member would see a part of the virtual world created by the graphics generator using the terrain data base and information arriving via the net regarding the movements and status of other simulated vehicles and battle effects - the precise part being defined by the crew member's line of sight: forward for the tank driver or from any of three viewing ports in a rotatable turret for the tank commander. With the shift from centralized processing to autonomous, distributed processing, the concept of data communication changed. Each simulator can communicate with every other simulator instead of with a central mainframe computer. In addition, each simulator is responsible for what it represents on its displays. Each simulator's microprocessor carries a model for all of the objects on the network, including itself, that describes that object, its state, and activity and is responsible for updating that model when something changes. The DIS architecture is an open architecture based on the International Standards Organization's Basic Reference Model for Open Systems Interconnection (OSI): ISO 7498-1984. The ISOOSI networking standard provides a seven-layer structure that specifies standards and protocols covering everything from the physical network to the data interchange between simulators. There are specific standards for communication over the long-distance network, for electronic communication for each particular type of local area network, and for the particular application, in this case the DIS simulation.

Uses and Limitations of DIS. It can be assumed that the whole is the sum of the parts and that therefore with enough simulators one could simulate a large battle, other considerations may supervene. For example, SIMNET focused on tanks and other vehicles, and DIS does not yet handle the individual soldier well. Yet the humble foot soldier, modernly equipped, retains his key role in warfare. The considerable antitank potential of today's infantry makes the foot soldier an important player on the tanks' battlefield and the key to the tanks' survival should they venture into woods or urban areas. However, it may not be feasible, affordable, or necessary (for some training tasks) to populate a synthetic battlefield with as many dismounted troops as there would be on a real battlefield. Another problem is that most participants in a battle spend much more time waiting than fighting. Moreover, battle is a stochastic (i.e., random) process - actually, the result of many stochastic processes. To deduce valid results from a simulation, it would be necessary to simulate the stochastic processes 32 and to do so many times, so that typical outcomes and the range of outcomes can be discerned to 33. Considering the hours of inactivity that most trainees would endure in an accurate simulation, it is questionable whether the troops' training time (and simulator time) would be well spent in repeating the same scenario many times in order to estimate the expected outcome (e.g., losses) and the range of outcomes. Perhaps, if the goal were a simulation of a large battle, all of the forces should be semiautomated, not just one side's. Indeed, computerized combat models featuring large forces, in some cases resolved down to the vehicle level, have been available for sometime. These include Corps Battle Simulation, Concepts Evaluation Model, Janus, Joint Integrated Contingency Model, TACWAR, etc. SIMNET's use for large battles has been proposed for two different purposes. One is exercise, the other is simulation. In command post exercises (CPXs) they determine the combat outcomes resulting from the commanders' decisions. As simulations, they are used to develop answers to questions such as force sizing and deployment. In the latter vein, one possible use of DIS is "virtual prototyping," in which a candidate weapon would take its place on the simulated battlefield before it is even pro the effort and expense of production.

Simulator Networking is the best known example of a DIS system in the Department of Defense. It includes simulators of tactical command posts and of about 250 Abrams tanks and Bradley Fighting Vehicles, as well as recording and playback facilities, in 8 locations, including Fort Knox, Fort Hood, and Grafenwoehr, Germany. Separate exercises can be conducted on different terrains at each facility, or all facilities can operate together on the same terrain. This system is an acknowledged success, and it will soon be supplemented by the Close Combat Tactical Trainer (CCTT), an advanced and more capable system with about 560 simulators at 12 fixed locations and 12 mobile sets for temporary locations. SIMNET was the first system to achieve routine "true interactive simulator networking for collective training of combat skills in military units from mechanized platoons to battalions". It was designed for and is limited to the Army. Other than a number of technology demonstrations, MDT2 is the first system-actually a test bed of a possible system - to support collective training of units from different services on a common mission, that of CAS. This was achievable only by solving several engineering and technical problems.

Each simulator creates an appropriate environmental representation based on the information received from other simulators and its own state information. Each simulator creates its own virtual world using standard simulator technologies (i.e., computer image generation, display, communication, and host computers). The number of entities that can participate in a battle is limited now to about 100,000 because of bandwidth and other limitations. The term "entity" includes not only vehicles that move, but objects, such as bridges or buildings that change their state if they are hit by a weapon.

The emergence of distributed interaction simulation has greatly expanded the application range of computer simulation in defense system analysis. The Metasynthesis Simulation Environment established by DIS could provide huge potential effects that could not be brought by former simulation technology. It could not only study the process, results and tactical issues of one regional battling, but also study multi-issue of military strategy, weapon system and high-level defense system [5]. DIS could be regarded as a new technical means of producing revolution for the development of defense system analysis. Presently, DIS is at the active exploration and research stage in domestic, and has obtained certain achievements. The active functions in army combat simulation have been widely accepted. With the continuous development of DIS technical research, it will drive the sustained development of army combat simulation theory and technology of army combat in the future. Three simulation levels or mission profiles are to be supported by WARSIM 2000. These are:

Multi-echelon Command Post Exercises. These support training simulation operations from corps level down through brigade headquarters. Training occurs simultaneously in an integrated scenario. Duration for multi-echelon CPXs is from four to nine days. Depending on participating units (i.e., corps or division), operations are continuous for 96-198 hours. This is the highest-level operating mode [6].

Single-echelon Command Post Exercises. Simulation exercises for battalions and brigades, and within service schools, are supported at this level. Commander and battle staff of the unit undergoing training audits the simulation from either actual CPs in the field or from mock-ups. Higher and subordinate and adjacent unit personnel participation is supported. Operations are conducted over a period of three to four days. Operations are continuous for 60-78 hours. Up to six simultaneously occurring and independent single-echelon CPXs will be supported.

Seminar mode. The least strenuous operational level supports exercises of active and reserve units and institutions. Operations take place during a one to three day period and are continuous for a period of 20 to 25 hours. Up to six simultaneously occurring and independent training seminars will be supported.

The types of physical environments to be supported during training events by DIS are wide ranging. Simulations are to duplicate environments ranging from jungle, arctic and desert. Operational conditions to be supported are to include the initial and residual stages of NBC and CBW deployment, and include support for mobile, projected, fixed-smoke effect and flame weapons, as well as reduced visibility conditions and night.

Subwarfare and special operations forces operations are to specifically be accommodated by the system. Training events are to support small unit infiltration, reconnaissance and search, locate and annihilate (SLAM) missions against targets military and civilian, including supply points, bridges, dams, weapons dumps and power generation stations. The simulated training events will enable SOF to utilize exotic equipment such as laser target designators to enhance delivery of PGMs and duplicate elite unit movement through battlespace that is stealthier than that of conventional infantry. EW, PsyOps, deception, terrorist acts and the taking of enemy prisoners of war (EPW) are also to be accommodated.

The capabilities of fixed and rotary wing special operations aircraft to perform infiltration and extraction operations from denied areas, including NOE and SAR, are to be duplicated in WARSIM 2000 training events. Space, air, naval and amphibious operations must also be represented as they impact on Army operations in a realistic manner during simulation exercises.

After-action reviews (AARs) can be supported via an AAR and Evaluation System (AARES). AARES will utilize several formats optimized to record training events specified by users and respond to statistical queries, even during the course of simulated exercises. Real-time false three dimensional screen displays, overhead viewgraphs superimposed on maps and showing the location of units in conjunction with symbol graphics and text messages are some of these formats [7]. Mission commanders and training supervisors will have the capability of executing database search operations of individual or multiple training events in order to generate standardized briefing reports. AARES is also to include support for the Tactical Decision Support System (TDSS).

While there is a clear mission for DIS-compliant training applications and technologies, especially in the area of infantry and special forces operations and large-scale combined arms battles against multiple or composite threat forces, critics have cited a number of drawbacks to full implementation of advanced distributed interactive simulation as a viable training modality.

The most common of the concern issues of affordability and technological feasibility. At the present time it is still generally less expensive to set up and conduct training simulations in the conventional way, and in some cases, to actually put troops on the ground. Simulator sickness is another common problem connected with prolonged exposure to immersive environments, given the current state of the art. It is caused by the discrepancy between visual motion cues generated by the system and those provided by the human senses. In interactive, immersive networks these symptoms can be exacerbated by the added stresses to the human nervous system brought on by update lag-time, producing such reactions as headache, nausea and vertigo.

Significant improvements in graphic fidelity, terrain representation, network throughput, protocol sharing and system security will need to be made, and funding issues will need to be resolved, before distributed synthetic battle spaces become commonplace training environments. But necessity has always been the mother of invention, and economic imperatives drive these resource-scarce times. In 1988, Operation Reforger staged corps-level combat exercises in Europe at a reported cost of some US $53.9 million, while a simulated version of Reforger staged in 1992 cost less than half and generated abundant after-action data that could be analyzed in depth. To mitigate the limitations on live-fly training, the United Kingdom's Royal Air Force (RAF), the Swedish Air Force (SwAF), and the Royal Australian Air Force(RAAF) used simulation-based training in preparation for upcoming Live fire exercises. The RAF and SwAF used distributed simulation training to prepare fighter pilots for Red Flag exercises conducted in the southwest US while the RAAF prepared Air Battle Managers (ABMs) for a Pitch Black exercise in the Northern Territory of Australia. The US Air Force Research Laboratory (AFRL), Warfighter Readiness Research Division working in cooperation withthe UK's Defence Science and Technology Laboratory (Dstl), the Swedish Defence Research Agency's Air Combat Simulation Centre (Flygvapnets Luftstridssimulerings center [FLSC]), and Australia's Defence Science and Technology Organisation (DSTO) helped to design and develop a program of simulator training for each nation's warfighters and to collect follow-on data at the exercise to evaluate the effectiveness of the training [3].

Through the design and analysis of concepts in controlled synthetic environments, distributed interactive simulation offers increased savings in time and money by reducing the need for expensive mock-ups and field testing. Synthetic environments enhance the possibility for exploring various design options in full battlefield context, allowing workers to design and assess concepts that could not be explored using traditional approaches because of safety, environmental, and cost considerations. Distributed interactive simulation can thus be used Army-wide to accelerate research and to permit advances in technology to be brought to the field in a timely fashion, helping to assure technological superiority on the battlefield.

The Defense Science Board (DSB) Task Force on Simulation, Readiness, and Prototyping defines simulation as "everything except combat" with three integral components - live (operations with real equipment in the field); constructive (war games, models, analytical tools); and virtual (systems and troops in simulators fighting on synthetic battlefields). While the first two components are technically mature, the virtual component is now evolving. Virtual capability is improving through technology advances in high-performance computing (HPC), communication, artificial intelligence (AI), and synthetic environment realization.

The near-term priority is to establish an Advanced Distributed Simulation (ADS) infrastructure to improve training and force readiness. The ADS infrastructure includes the following:

High-performance computing;

Real-time, large-scale networking;

Data and application software methodologies for interoperability, scalability, and realism;

Multilevel secure, hierarchical, open architecture standards, interfaces, and products [8].

Conclusions

Computer combat simulation could describe and study the operational procedures according to the given or assumed procedures and data, analyze the multi facts that include combat strength, and prime relations between opposite parties quantitatively and accurately. It could also simulate certain military operations that are not permitted or hard to be studied in practice, show the confrontation of opposite parties and randomness of battling activities considerably, and also test the impacts of one factor on general battling effects etc. This type of combat simulation could also be used to test strategy and plan, find the defects and predict its effects, evaluate effectiveness of weapon system, and inspire new operating thoughts and modes. With the adoption of the systematic and scientific research method, the process of researching becomes more vivid and the results of study are more creditable. Therefore, technology of distributed interactive simulation has proven worth incorporating into learning process of Army Academy.

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Технологія розподіленого моделювання та її застосування у бойовій підготовці Сухопутних військ

М.Ю. Яковлев, О.М. Совгар, Є.В. Рижов

У статті надано огляд технології розподіленого інтерактивного моделювання, її складових компонентів та застосування у бойовій підготовці Сухопутних військ.

***Ключові слова**: розподілене інтерактивне моделювання, бойова підготовка, командно-штабне навчання.*

Технология распределенного моделирования и её применение в боевой подготовке Сухопутных войск

М.Ю. Яковлев, О.М. Совгар, Е.В. Рыжов

В статье дан обзор технологии распределенного интерактивного моделирования, её составляющих компонентов и применение в боевой подготовке Сухопутных войск.

***Ключевые слова:** распределенное интерактивное моделирование, боевая подготовка, командно-штабные учения.*