DEVELOPING AN AFTER ACTION REVIEW SYSTEM FOR VIRTUAL DISMOUNTED INFANTRY SIMULATIONS

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ABSTRACT

The Dismounted Infantry Virtual After Action Review System (DIVAARS) is one component of a research program to develop effective Virtual Environment (VE) training techniques for dismounted Infantry leaders, soldiers, and units. This paper describes the development of the system, the conduct of the soldier evaluations, and the resulting system enhancements. DIVAARS is designed to provide trainees with a common understanding of what happened during an exercise and why it happened, so that they can identify ways to improve their performance, and to facilitate data analysis and presentation to support both training feedback and research and development. Determining what happened during an exercise is particularly difficult in urban terrain, where buildings limit the portion of the battlefield that can be observed by any one person. DIVAARS software runs on a Linux platform and can be hosted on a Pentium III PC. Key capabilities of the system are: digital videodisc (DVD)-like replay with synchronized audio and video, the capability to mark times and views during an exercise and jump to them during the AAR, and tabular and graphic data summaries. Several features are especially useful for exercises conducted in urban terrain: interiors of individual floors of multi-story buildings can be selected for viewing, individual soldiers can be identified, and visual traces of their movements can be presented. An evaluation of the system was conducted at the Dismounted BattleSpace BattleLab, Fort Benning, GA. Squads composed of Infantry soldiers and computer-generated forces conducted exercises in VE models of the Shughart Gordon enclave over a 5-day period. Questionnaires and interviews were used to evaluate the system. The system was rated positively. Several areas for enhancements were identified and implemented.

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INTRODUCTION

The Dismounted Infantry Virtual After Action Review System (DIVAARS) is one component of a research program to develop effective Virtual Environment (VE) training techniques for dismounted Infantry leaders, soldiers, and units. This paper first describes the goals of DIVAARS in the context of Army training needs and previous research with AAR systems. Next, it presents an overview of the system concept followed by descriptions of specific features, system hardware, and system software. An evaluation of DIVAARS conducted with Infantry soldiers is then described. System enhancements that followed from the soldier evaluation are presented. The paper concludes with a look at future research needs.

ARMY NEED

The U.S. Army requires a dismounted soldier simulation capability to meet multiple needs. The first need is to enable dismounted leaders, soldiers, and units to train effectively even if they do not have frequent opportunity to participate in high fidelity field training exercises. The second need is for effective mission rehearsal tools that prepare leaders, soldiers, and units for specific combat missions in all types of terrain. The third need is for inexpensive and high fidelity prototyping and testing systems that will allow decision makers to explore and evaluate potential changes in doctrine, organizations, equipment, and soldier characteristics. These needs are very important today; they are likely to be critically important as the Objective Force becomes a reality.

In response to these needs, the U.S. Army Research Institute Simulator Systems (ARI-SSRU) and Infantry Forces Research Units (ARI-IFRU), the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM), and the U.S. Army Research Laboratory Human Research and Engineering Directorate (ARL-HRED) and Computational and Information Sciences Directorate (ARL-CISD) are participating in a joint Science and Technology Objective (STO) entitled "Virtual Environments for Dismounted Soldier Simulation, Training and Mission Rehearsal." The goal of the research is to develop a demonstration dismounted leader trainer at the fire team, squad, and platoon level. Leader trainees will be able to execute a series of realistic training scenarios (combat operations and support operations) in the simulator. Repeated practice, enhanced by training features and After Action Reviews (AARs) will build decision-making and coordination skills. Computer-controlled or semi-automated agents will represent subordinates, other friendly forces, enemy forces, and civilians. The intent is to have a training system that is realistic and effective, yet requires a fairly low level of personnel support for subordinates and role players.

A key component of the dismounted leader trainer is an After Action Review (AAR) system. The purpose of an AAR system is to help trainees develop a common understanding of what happened during an exercise and why it happened, so that they can identify ways to improve their performance. An AAR system can also facilitate data analysis, in order to support training feedback and research and development.

AFTER ACTION REVIEW SYSTEMS

In the early 1970's major changes occurred in Army training, with the use of objective standards ousting subjective evaluations. Evaluating complex collective training tasks presented a challenge requiring more than gross performance metrics. The AAR provided a structured method of facilitating learning from complex experiences that are often very ambiguous (Sullivan & Harper, 1996). Within ten years the AAR had become an essential component of Army training that could be applied across category, branch, and echelon of Army training. Morrison and Meliza (1999) present an excellent review of both the historical and conceptual foundations of the After Action Review method.

As with live and constructive training, the AAR method became a crucial component of training with virtual simulations. For example, the Unit Performance Assessment System (UPAS) and the Automated Training Analysis and Feedback System (ATAFS) were developed for the SIMNET system. These AAR systems addressed technical issues of extracting information from the simulation data streams, reducing operator workload, and producing aids and displays that went far beyond a simple replay of the exercise. Meliza (1998) provided descriptions of desirable AAR "aids" (or AAR system capabilities) and the utility of each based on lessons learned from those systems. He included aids such as two-dimensional and three-dimensional animated plan view replays, snapshots, battle flow diagrams, fire fight displays, exercise timelines, tables and graphs, and behavioral checklists. Our goal was to develop an AAR system that incorporated those types of aids where possible, but tailored them to meet the unique requirements of small unit dismounted Infantry training in virtual simulators. This required an AAR system that could not just replay an exercise, but could in addition support the presentation of exercise events and data in a manner that would facilitate trainee understanding of what happened, why it happened, and how to improve.

The development of this system involved combining lessons learned from previous AAR systems, such as UPAS and ATAFS, with the unique requirements of small unit dismounted Infantry training for urban missions. Previous research with live and virtual simulations, summarized by Morrison and Meliza (1999) indicated that at the level of small units in close combat, the critical actions involve fire and maneuver that are best shown spatially in relation to the terrain and enemy. That translates to a need for 3-D replays and 2-D map displays, with synchronized communications. In addition, determining what happened during an exercise is particularly difficult in a Military Operations in Urban Terrain (MOUT) environment, where buildings and other structures break up the visual field and limit the portion of the battlefield that can be observed by any one person. This established a need for special viewing capabilities, such as the capability to observe action within buildings.

For the traditional AAR goal of determining "what" happened during a mission, the DIVAARS replay recreates exactly what happened during the mission. During the replay the unit members can observe the location, posture, and actions of all the other members. And, unlike live field training, DIVAARS can replay mission action exactly as viewed by any of the participants. These features not only support the trainees' explanation of why events happened but also help the unit members develop shared mental models of individual and unit tasks. Watching the replay may also strengthen group identification and cohesiveness. Finally, several DIVAARS features (such as depicting critical events in slow motion and from multiple perspectives) enhance memory so those lessons learned are more likely to be employed in subsequent training and missions. .

SYSTEM CONCEPT

AAR Leaders are central to the design and operation of DIVAARS. The AAR Leaders observe what happens during the conduct of an exercise and prepare a presentation that will lead the unit to an understanding of what, why, and how. This presentation should be both interactive and efficient. An implication is that AAR Leaders need to be able to use the system in two modes. First, during the exercise, they need to be able to observe the exercise in real time and annotate it with their observations, particularly to be able to mark or highlight both the critical events and the positions from which they can best be observed. Second, during the AAR, they need to be able to display key events and data quickly and efficiently. Since AAR Leaders are expected to be subject matter experts, not computer specialists, the operation of DIVAARS needs to be as simple and straightforward as possible.

FEATURES

DIVAARS was developed in two phases. The first phase ended in September 2001 with the conduct of an evaluation during a series of dismounted Infantry exercises. The second phase ended in September 2002, again with an evaluation. Descriptions of Phase I features, the 2001 evaluation, and Phase II improvements follow. The emphasis will be on unique DIVAARS capabilities. Figure 1 shows a sample DIVAARS display with many of these features.

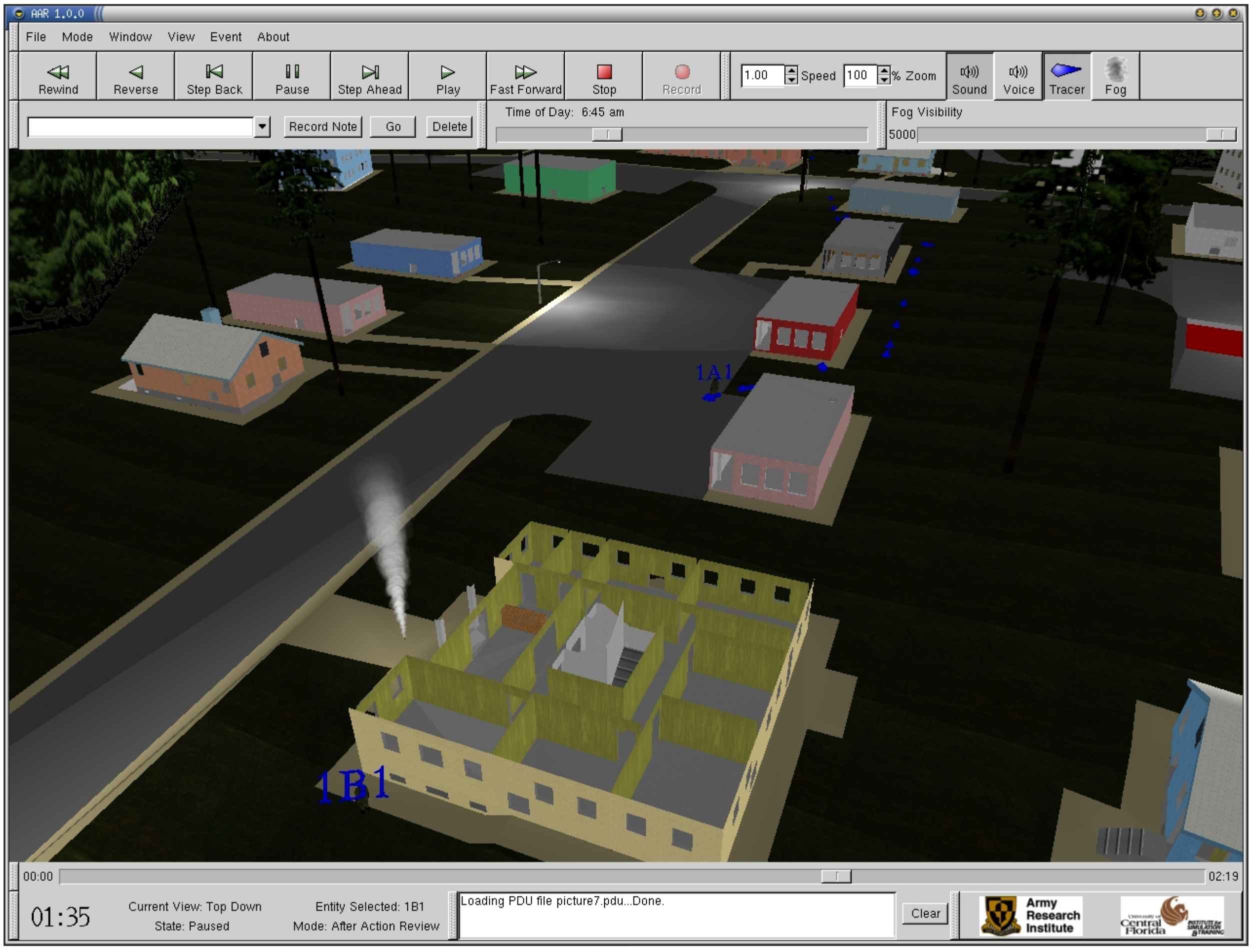

Figure 1. DIVAARS main display.

Playback. A linear beginning-to-end playback is unlikely to be either the best or most efficient way to provide the trainees with an understanding of what happened during an exercise. The replay system includes actions such as pause, stop, record, play, step forward, fast-forward, rewind, fast-reverse, and step-reverse. Variable playback speeds are available. Furthermore, the AAR Leader has the capability to mark events during the exercise, and jump directly to them during the AAR.

Viewing Modes. Viewing scenario events from different perspectives is essential to understanding what happened. Multiple viewing modes are available to the AAR Leader during both the exercise and the AAR. Ten preset views can be selected at any time prior to or during the exercise for immediate use. These can be used for perspectives or positions that the AAR Leader thinks will be useful, such as the view from an enemy position. The variety of viewing modes provides added capabilities during the AAR process.

- Top-Down – A view of the database looking straight down from above. It can be moved left, right, up, down, and zoomed in or out. The AAR Leader can also lock the view onto an entity, in which case it will stay centered directly above that entity as it moves through the database.
- 2D View - This is the traditional plan view display. It is the same as Top-Down except that depth perspective is not shown.
- Entity View – By selecting any entity, (including enemy or civilian), the AAR Leader can see and display exactly what that entity sees. This includes the effects of head turning and posture changes.
- Fly Mode – The AAR Leader can “fly” through the database using the mouse for control.

During the course of a replay the trainees will be able to see the mission from a number of perspectives. The top down, 2D, and fly views, views that are never available to them during the mission exercise, promote seeing the big picture and learning to see the battlefield. The entity view, seeing through the eyes of others, supports a number of training functions. Did the leaders see an action or problem but fail to respond, or were they not looking in the right direction at all? Do squad members maintain 360^0 security and report promptly? What was the view from likely and actual enemy positions? The DIVAARS replay provides unequivocal answers to those questions.

Movement Tracks. Movement tracks show, in a single view, the path an entity traveled during an exercise. Markers are displayed at fixed time intervals. Every fifth marker is a different shape than the four preceding it. The display of these markers can be turned on and off. The movement tracks provide a clear display of the path and speed of movement of each member of the unit. In addition, they provide indications of the unit formations and of the location and duration of halts in movement. Thus, the AAR Leader may elect to skip or fast-forward through portions of the replay, knowing that the movement traces for those skipped segments will be observable when the replay is resumed.

Entity Identifier. Friendly force avatars in the DIVAARS, as in the virtual simulators, are identical. A unique identifier, as given in the entity marking field of the DIS Entity State PDU, is shown above the avatar of each unit member. For example, 2SL is the identifier for the squad leader, second squad. The entity identifiers change size to be readable across all levels of zooming.

Digital Recording and Playback of Audio Program. Audio communications within a unit are important scenario events. DIVAARS records and plays back audio content for all scenarios. This system was developed and tested with an ASTi Digital Audio Communications System (DACS: Advanced Simulation Technology, Inc., 2001). The ASTi system converts all voice communications from live participants to digital messages and outputs them on a DIS network using Transmitter/Signal/Receiver PDUs. In addition, DIVAARS records environmental audio information (for example gunshots) from the simulator via the DIS Fire and Detonation PDUs. The DIS timestamps are used to play back the audio at the correct moment during the AAR replay.

Viewing Floors of Building. The AAR Leader must be able to follow the action in MOUT scenarios even when a unit enters a building. The AAR Leader can select a building and then select a floor of that building to be displayed. Using this feature, the operator can view and display the avatars going through a building without the problem of upper floors being in the way.

Dynamic Terrain Server. ARL-CISD has developed a Dynamic Terrain server that creates, in real-time, holes in building and rubble from weapon fire. DIVAARS receives these PDU messages and updates the display for any changes.

Bullet Lines. This feature helps to determine what objects are being shot by each entity, and to identify patterns of unit fire. Bullet flight lines are shown for all weapon firings. The line traces a shot's origin and destination. It is the same color as the originating entity. These bullet lines gradually fade away.

Event Data Collection and Display. DIVAARS has the capability to track many events including shots fired, kills by entities, movement, and posture changes. These data can be shown in a tabular format or graphical display. The AAR Leader can use them as needed to make various teaching points. They can also be used to support subsequent data analysis for research and development applications. Custom events defined by the operator are automatically flagged and can be jumped to during playback. Ten different tables and graphs are available:

- Shots fired, by entity and unit
- Kills, by entity and unit
- Killer-Victim table that shows who killed whom, with the option to show the angle of the killing shot (front, flank, or back) or the posture of the victim (standing, kneeling, or prone)
- Shots as a function of time, by entity, unit, and weapon
- Kills as a function of time, by entity, unit, and weapon
- Kills by distance from killer to victim, by entity, unit, and weapon
- Rate of movement of each entity, and aggregated at fire team and squad levels
- Percentage of time friendly units were stationary
- Percentage of time friendly units were in different postures
- Display of user-defined events

HARDWARE AND SOFTWARE

The DIVAARS main system can currently operate on PC (Linux) and SGI (IRIX) platforms. The PC typically used is a dual Pentium III, 933 MHz system with 512MB RAM and a hardware accelerated graphics card (a GeForce2 card from nVidia is typical). RedHat Linux 7.x is used, although DIVAARS should work on other Linux distributions. A second PC is used for the voice communication capture and replay. This system is a single Pentium III, 800 MHz with 256MB RAM and runs Windows 2000. A sound card for each major channel recorded is necessary with the outputs mixed to a single set of speakers.

DIVAARS uses the Virtual Environment Software Sandbox (VESS; University of Central Florida, 2002), an in-house developed and freely available library. VESS is designed to simplify and expedite the development of virtual environments. VESS itself is currently built on top of OpenGL Performer, which was used for rendering the virtual environment. A version of VESS built on Open Scenegraph is planned.

EVALUATION

The DIVAARS was evaluated as part of the Virtual Environments for Dismounted Soldier Simulation STO FY 01 Culminating Event (CE), held at the Dismounted BattleSpace BattleLab Simulation Laboratory, Fort Benning, GA in September 2001. The purpose of the CE was to obtain information and data about the functional capability, usability, interoperability, and, to a lesser extent, the effectiveness of the VE STO-developed technologies in a realistic setting.

A simulation network was established to support the conduct of a series of tactical exercises by squads composed of a mixture of "real" soldiers in immersive simulators and semi-automated soldiers. Semi-automated enemy and neutral forces and one real role player using a desktop simulator also participated. Systems on the network communicated via DIS 2.0.4 protocols. The following systems were included:

- Five Soldier Visualization Station (SVS) immersive individual soldier simulators used by the squad leader, the fire team leaders, and two of the three fire team members. Radio headsets permitted verbal communication among the soldiers.
- One Omni-Directional Treadmill (ODT) station used by the third fire team member. It was also equipped with a radio headset.
- One Voice Recognition PC used to recognize the Fire Team B Leader's voice commands and translate them into commands that could be used by DISAF.
- One Dynamic Terrain Server, to calculate damage to structures by weapons impacts.
- One BattleMaster/ Dismounted Infantry Semi-Automated Forces (DISAF) Operator Station. The DIS SAF Operator and the Exercise Controller used this station.
- One Desktop SVS used by a role player.
- DIVAARS.

Eight different scenarios were used during the culminating event. They consisted of a variety of peacekeeping and MOUT operations taking place in a virtual representation of the Shughart Gordon MOUT site, Fort Polk, Louisiana.

One group of six soldiers participated for one day, and two groups of six soldiers participated for two days each. They were assigned duty positions for the exercises based on their rank: squad leader, fire team leader, or fire team member. All soldiers received instruction and practice on the use of the SVS and additional training specific to their duty position, then participated in one familiarization exercise and either two or seven training exercises. Each exercise session consisted of a verbal delivery of the mission order by the Exercise Controller, usually supplemented by a virtual demonstration. The Squad Leader briefed the mission to the squad. Soldiers then moved to their simulators and the exercise began. At its completion, the soldiers reported to the DIVAARS station for an AAR. Soldiers were then given a break prior to starting the next exercise sequence. Whether they participated for one or two days, all soldiers were given a series of questionnaires at the completion of their last day.

The AAR system was used the same way in each of the exercises. The Exercise Controller, who also served as the AAR Leader, verbally identified events, viewpoints, and actions that he wished to be shown during the AAR. The AAR system operator, who had direct control of the AAR system, actually implemented them as directed using the keyboard and mouse. During the AAR itself, the AAR Leader controlled the AAR and interacted with the soldiers while the AAR system operator called up the exercise segments, views, and data summaries requested by the AAR Leader. See Figure 2. This arrangement, born of necessity, was not ideal. Planning the AAR was a secondary task for the Exercise Controller, who was primarily concerned with controlling the flow of the exercise.

EVALUATION RESULTS

Overall, DIVAARS integration was successful. In general, the problems encountered were the result of different approaches by the different system developers to transmit information about articulated human figures using DIS protocols. Some problems were fixed during the CE itself. The most serious problem encountered was an inability to record intelligible voice communications.

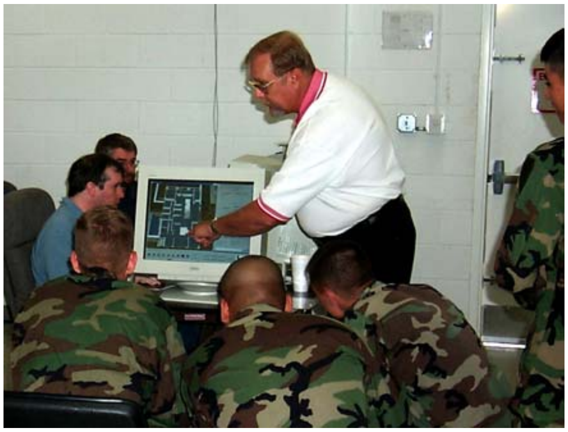

Figure 2. The AAR Leader conducting an AAR, with the support of the DIVAARS Operator.

Data about the effectiveness of DIVAARS comes from questionnaires completed by the soldiers. Their responses are summarized in Table 1. Overall, the soldiers rated DIVAARS positively. More than 83% of the soldiers agreed or strongly agreed with eight of the nine positive statements about DIVAARS. All agreed or strongly agreed that DIVAARS made it easy to determine what happened during a mission. The least positive rating was that only 56% agreed or strongly agreed that it was effective in replaying communications. Since the communications played by the AAR system were rarely intelligible, this suggests that the ratings benefited from a positive “halo effect”. That is, the soldiers had a generally favorable impression of the AAR system, and tended to rate it on the basis of that overall impression, as well as the specific item being rated. This does not mean that the soldiers were unwilling to give negative ratings; aspects of other system components involved in the CE did receive negative ratings.

Fire team and squad leaders were the primary training audience for the exercises. They were asked to rate how effective the exercises were in improving their skills on each of 11 tasks at the end of each day of exercises. The results are shown in Table 2. The percentage of leaders indicating that their skills had improved on each task ranged from 53% to 100%, with median of 80%. General tasks (coordination, control) tended to show more improvement than specific, highly structured battle drills.

While these data do not show that DIVAARS improved training effectiveness, they do establish two critical links. First, DIVAARS helped soldiers and leaders understand what happened and why it happened during the exercises, and helped them identify ways to improve their performance. Second, leaders felt that their performance improved as a result of the total training experience, including the DIVAARS AARs. Taken together, they show the potential of DIVAARS for improving training effectiveness.

PROGRAM IMPROVEMENTS

The lessons learned from the 2001 Culminating Event, plus additional planned improvements, have produced the following changes to DIVAARS.

AAR Leader Enhancements/User Interface. These changes were made to facilitate AAR Leader operation and use of DIVAARS. The user interface library GIMP Tool Kit was used to create a Windows-like user interface. The AAR Leader can now click on an entity and get a pop-up menu. This pop-up menu includes choices specific to that entity, such as see entity view, link top-down view to that entity, and turn movement tracks on or off. Clicking on a building gives the AAR Leader a pop-up menu to select the floor to be displayed. Zooming is now based on percentages rather than absolute values. Time of day was mapped to a 24-hour period. A “Preferences” window is now available to set preferences such as network port, marking intervals, and step amounts. Current time is displayed on a slide bar, which can be dragged to change the current time of the replay. Other enhancements include:

- Replay of sounds can be turned on and off using the Sound button.
- Replay of entity voice communication can be turned on and off using the Voice button.
- User-defined grouping has been added. These groupings are displayed in a tree format in a dialog box.
- The AAR Leader can select an entity or a group by clicking on it in the dialog box.
- Statistics gathered during playback mode can now be displayed as they are gathered.
- Tables for individual entities now are accessible by either right clicking on an entity or selecting it in the list entity dialog box.
- The display of entity identifiers can be turned on and off.

Table 1 Soldier Ratings of DIVAARS

The AAR system...	% Responding				
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
was effective in displaying movement outside of buildings.	27.8%	61.1%	11.1%	0.0%	0.0%
was effective in displaying movement inside of buildings.	33.3%	50.0%	11.1%	5.6%	0.0%
was effective in replaying communications.	27.8%	27.8%	33.3%	5.6%	5.6%
made it easy to determine what happened during a mission.	44.4%	55.6%	0.0%	0.0%	0.0%
made it easy to determine why things happened the way they did during a mission.	44.4%	38.9%	16.7%	0.0%	0.0%
made it easy to determine how to do better in accomplishing a mission.	27.8%	55.6%	16.7%	0.0%	0.0%
made it easy to determine the order in which key events occurred during the mission.	33.3%	66.7%	0.0%	0.0%	0.0%
was more effective than conducting an AAR without any visual or audio playback (just talking).	50.0%	33.3%	11.1%	0.0%	5.6%
helped me understand what occurred during the exercise.	33.3%	61.1%	5.6%	0.0%	0.0%

Note. N = 18.

Table 2 Squad and Fire Team Leader Training Effectiveness Ratings

Task	% Indicating Improvement
Coordinate activities with your chain of command.	100%
Assess the tactical situation.	93%
Squad/fire team communication and coordination.	80%
Control squad or fire team movement during assault.	80%
Control squad or fire team movement while not in contact with the enemy.	80%
Control your squad or fire team.	80%
React to Contact Battle Drill.	80%
Plan a tactical operation.	73%
Locate known or suspected enemy positions.	67%
Clear a building.	57%
Clear a room.	53%

Note. N=15. Squad and Fire Team Leaders who participated for two days completed the questionnaire at the end of each day.

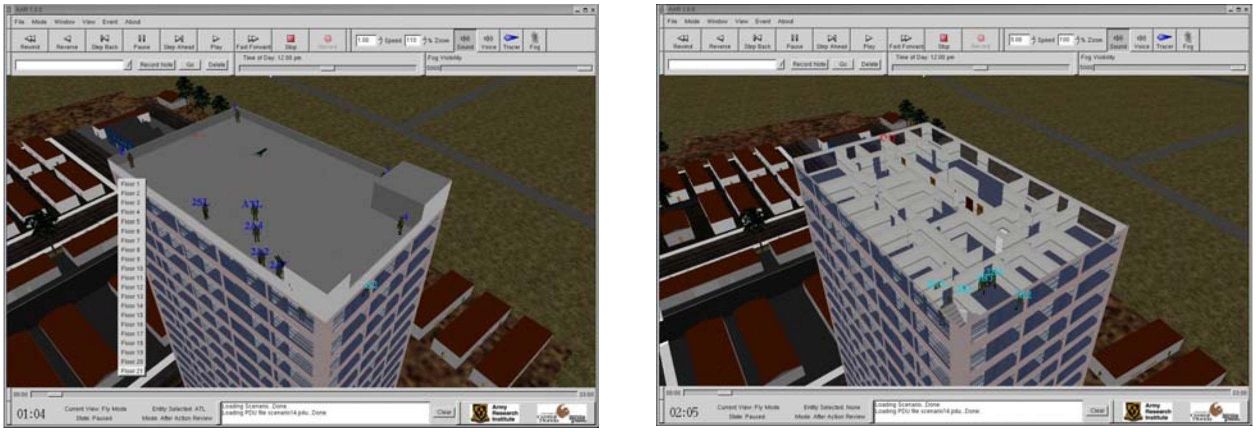

Figure 3. Building floor selection and display.

Visual Display Improvements. These changes were made to make it easier for the soldiers and the AAR leader to view and understand AAR events and data. The second monitor capability of the video card was used to present the soldiers with a larger view of only the virtual scene instead of a copy of the full interface. Tables and graphs were re-designed to improve visibility from a distance. Methods for showing dead players and kneeling and prone postures were improved.

Visual Effects. These changes were required to provide visual display capabilities equivalent to those the soldiers had in their individual simulators. The display of lampposts and their light sources was added. A particle system class was created to produce smoke columns. An adjustable scale for a 24-hour Time of Day value is used to determine the amount of ambient light to be displayed. Fog can be added to the display.

Display Building Floor. It was discovered that entities on floors in a building above that selected for viewing were interfering with the view of the desired floor. DIVAARS now "removes" entities on floors above the selected floor. This makes the viewing of the selection much easier. Figure 3 shows a high rise with entities on the top floor removed when viewing the lower floor.

Audio Recording and Playback. The audio recording and playback did not work correctly during the 2001 CE because DIVAARS was limited to recording on one audio channel, while the audio network was set up with four audio channels. The new audio recording and playback system works with an ASTi radio using 4 transmitter channels.

PLANNED 2002 EVALUATION

DIVAARS will be a part of the VE STO FY 02 Culminating Event, which will take place at the Dismounted BattleSpace BattleLab Simulation Laboratory, Fort Benning, during August 2002. While the overall structure of the event will be similar to the 2001 CE, there will be several changes that impact DIVAARS. First, different individuals will fill the roles of the Exercise Controller and AAR Leader. The AAR leader will also be the primary DIVAARS operator. This will give the AAR Leader more time to plan for and prepare for the AAR, and enable him to become more proficient in the use of DIVAARS. This should not only improve the quality of the AAR; it will also provide better feedback about the design of the operator interface. A more formal structure for the AAR itself will be developed to insure that all the system capabilities are used when they are appropriate. Both of these changes should provide better feedback about the use of DIVAARS in a realistic setting. The culminating event will be structured so that objective measures of leader and unit training effectiveness can be obtained.

FUTURE DIRECTIONS

This research and development program will formally conclude in September 2002. The DIVAARS software will be left with the Dismounted BattleSpace BattleLab for use in their research and training functions. The software will also be made freely available for use is other government programs. We believe that DIVAARS can provide a baseline system that can be tailored for use with virtual training programs. The Army's Objective Force Warrior program will need simulation-based training and feedback. Virtual simulations to train decision-making skills of small unit leaders within the Army schoolhouse, such as those used by Pleban, Eakin, Salter, and Matthews (2001), are also a candidate. Finally, there is also the potential for extension to non-combat domains, such as the Virtual Emergency Response Training System (VERTS).

There are a number of new features that could be added to DIVAARS, given time and resources. The most important would be the capability to produce multi-media take home packages, so that training and units could review their exercises after their training experience has been completed. The second would be the capability to incorporate scenario control information, such as phase lines and boundaries, into the AAR. The third would be the capability to automatically detect and mark certain critical events, such as fratricide, without intervention by the AAR Leader.

Finally, there is a wide open research area of AAR capabilities and training effectiveness. While the AAR method is widely accepted and believed to be effective, there is little empirical data available that indicates what AAR capabilities or features contribute most to training effectiveness, or how they should be used to maximize that contribution.

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