Integrating Intelligent Structured Training with a Virtual Dismounted Environment

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ABSTRACT

The advancing state of the art in dismounted embedded training makes use of helmet-mounted displays, man-wearable computers, and other immersive hardware to construct increasingly engaging environments. Within such a frame work, structured training methods provide a means to achieve learning objectives and concept retention, with minimal instructor involvement. Intelligent structured training applies real-time automated evaluation and feedback methods based on Intelligent Tutoring Systems (ITS) techniques. This paper reviews results from the integration of an Intelligent Structured Trainer with the embedded Virtual Warrior Soldier prototype developed for the Army RDECOM Simulation and Training Technology Center. Army subject matter experts defined dismounted training objectives and specific requirements for integrated evaluation mechanisms. The paper discusses three areas of research results, both in terms of direct research findings and also how these findings can be applied for future work. First, the effort identified the nature of the data that an integrated structured trainer consumes in order to generate useful real-time feedback for dismounted Soldiers. This data includes not only state information direct from the simulation, but also data reflecting Soldier actions in the primary interface and secondary Command and Control interfaces. Data categories can be generalized and catalogued for future related training efforts. The second research outcome is an analysis of scenario authoring requirements, in terms of SAF (semi-automated forces) performance, terrain database accuracy and consistency, data protocols and availability, and the authoring process itself. Third, user feedback collected from initial experiments with human Participants provide several indicators for the areas of greatest fit or friction between the dismounted training objectives and a structured training approach. This helps define the road ahead, in setting goals for the usability and realism of the training environment, in identifying the dismounted task areas best suited to structured training, and in applying varied methods for automated feedback delivery.

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INTRODUCTION

The advancing state of the art in dismounted embedded training makes use of helmet-mounted displays, man-wearable computers, and other immersive hardware to construct increasingly engaging environments. Within such a framework, structured training methods provide a means to achieve learning objectives and concept retention, with minimal instructor involvement. Intelligent structured training applies real-time automated evaluation and feedback methods based on Intelligent Tutoring Systems (ITS) techniques. This paper reviews findings from the integration of an Intelligent Structured Trainer with the embedded Virtual Warrior Soldier prototype developed for the Army Research Development and Engineering Command (RDECOM) Simulation and Training Technology Center (STTC). Army subject matter experts defined dismounted training objectives and specific requirements for integrated evaluation mechanisms. The paper discusses three areas of research results, both in terms of direct research findings and also how these findings can be applied for future work.

First, the effort identified the nature of the data that an integrated structured trainer consumes in order to generate useful real-time feedback for dismounted Soldiers. These data include not only state information direct from the simulation, but also data reflecting Soldier actions in the primary interface and secondary Command and Control interfaces. Data categories can be generalized and catalogued for future related training efforts.

The second research outcome is an analysis of scenario authoring requirements following the process of constructing scenarios for the structured trainer and also developing a preliminary scenario authoring tool. This led to new insights regarding requisite performance criteria in terms of modeled behaviors in semi-automated forces (SAF), terrain database accuracy and consistency, data protocols and availability, and the authoring process itself.

Third, user feedback collected from initial experiments with human Participants provide several indicators for the areas of greatest fit or friction between the dismounted training objectives and a structured training approach. This helps define the road ahead, in setting goals for the usability and realism of the training environment, in identifying the dismounted task areas best suited to structured training, and in applying varied methods for feedback delivery.

BACKGROUND

Previous Structured Training Experiments

This research builds on a previous effort which integrated an Intelligent Structured Trainer with a Command and Control Vehicle (C2V) crewstation testbed for training experiments in a task area under the Army's Future Combat Systems (FCS) concept. Within this task area, the FCS Soldier manning a Command and Control Vehicle (C2V) crewstation testbed must remotely control robotic platforms to perform reconnaissance and engage the enemy. The objective was to mirror the embedded training context, where a great deal of future force training is planned to occur, and where instructors will not be available to provide tailored feedback during the execution of an exercise.

In a bi-directional integration with the C2V testbed, evaluation mechanisms monitor events in the simulation and testbed in real time, and deliver feedback during scenario execution as appropriate via messages published to the simulation environment. This procedure is performed by intelligent agents indexed to evaluation principles identified by subject matter experts. The agents are implemented in Behavior Transition Networks (BTNs), which resemble finite state machines with several extensions to make them more powerful for applications like hierarchical principle-based evaluations. The system also makes use of a toolset for BTN authoring and execution (Fu et al, 2003). The structured training experiments yielded significant findings in three result categories:

- Retention of procedural knowledge
- Quantity of procedural errors
- Retention of conceptual knowledge

For each of these categories, results were compared between two cases. The first case was automated immediate feedback from the structured trainer during the exercise. The second case was human-led after action review, where the only feedback was delayed until post-exercise. Immediate directive feedback was found to have a significant effect in reducing the number of errors committed while acquiring new procedural skills during training, as well as retention of these procedural skills. Specifically, the immediate feedback case resulted in significantly fewer procedural errors than the delayed feedback case. The two cases had comparable performance in retention of procedural knowledge, and delayed feedback had better results in retention of conceptual knowledge. However in each result category, performance measurements supported the conclusion that learning results did successfully occur from the use of the structured trainer (Jensen et al. 2005).

These experiments provided a basis for the effort, reported here, which aimed to port the same structured training approach to a markedly different application, training small-unit dismounted Infantry operations. By doing so, the goal was to highlight key training factors unique to the dismounted platform and lay out a roadmap for the accomplishment of learning results similar to those achieved with the C2V testbed and trainer.

Virtual Dismounted Training

Use of virtual reality systems for the individual Infantry Soldier has progressed quickly over the last ten years. The U.S. Army is fielding specific simulators that allow the Infantryman to train in virtual reality. Prior to the fielding of these systems, the Infantryman was largely ignored mainly due to the lack of available technology. These systems are housed in dedicated simulation centers which units visit to train in their mission essential tasks. This system is named the Squad Synthetic Environment (SSE) (Chisholm, 2003).

This virtual Infantry training system is located in the Dismounted Battlespace Battle Lab (DBBL) at Fort Benning, Georgia. The DBBL is located in a warehouse type building and is one of the first systems attempting to provide a fully immersive environment for the Infantry Soldier (Rodriguez, 2003).

The Squad Synthetic Environment is based on the Soldier Visualization System (SVS), manufactured by Advanced Interactive Systems (AIS). The Squad Synthetic Environment (SSE) is used in two forms: a fully immersive system that uses a CAVE, and a desktop version. The CAVE systems are approximately 15 feet by 30 feet by 10 feet in dimension (Miller, 2002), with sensors to determine the Soldier's location and posture. The helmet and weapon also have sensors to help determine the Soldier's viewpoint, and the location of any simulated rounds that he may fire (Gately, 2005). The other form is simply a desktop version, which has the same capabilities as the CAVE systems in terms of weapon selection and communications (Miller, 2002). Using the desktop version is an experience similar to many first person shooter games marketed to gamers.

The SSE has allowed the U.S Army to explore virtual training for the dismounted Infantry Soldier. A critical operational limitation of this system is its availability. Fort Benning, Georgia is responsible for training all Infantry Soldiers from the ranks of Private to Captain. The post also is the home of three Infantry battalions and a Ranger battalion. There are over three thousand Soldiers available for training each day, while the DBBL can only provide eighty stand-up modules for training (Gately, 2005). This is most likely not enough systems to provide a significant training benefit to the commanders and trainers who are responsible for training Soldiers. Desktop trainers can supplement the CAVE systems. The British Army has conducted a study on the effectiveness of desktop trainers for urban operations. Naturally, most Soldiers surveyed indicated that they prefer to train in a live environment. Most Soldiers also felt that the desktop trainer would be a useful tool for the leaders to sharpen their decision making and command and control skills. Slight performance improvement has also been reported in a section that received only virtual training before performing the collective task in the live environment. No instances of negative training were noted from those surveyed who trained in the virtual environment (Pennel, 2003).

Dismounted Player Unit Testbed

The testbed for the research reported in this paper was a prototype embedded trainer developed by General Dynamics, named Virtual Warrior (VW). The Virtual Warrior system (shown in Figure 1) incorporates movement tracking sensors with six degrees of freedom, independently tracking the head, leg, torso, and weapon. These sensors are integrated into the hardware and software interfaces.

Figure 1. Virtual Warrior Prototype

There are two physical controllers used with the VW; the Weapon User Interface or WUI, and the Soldier Control Unit Interface or SCUI. The WUI is essentially a joystick that allows the user to move forward, backwards, left, right, and toggle through certain tasks such as bore sighting and marking cleared rooms. The SCUI allows the user to view the situational awareness screen, send digital messages, use mouse controls, change posture, and reset the system.

Soldiers experience the virtual environment visually with the use of a helmet mounted display (HMD) which uses the existing bracket used for night vision goggles. The HMD is manufactured by eMagin, and provides an 800x600 binocular resolution and a 28 degree diagonal field of view. Stereo sound is also provided through speakers that have been adapted to the helmet. A specially implemented message box was developed as a popup that can appear in the 3D view when the integrated Intelligent Structured Trainer detected conditions meriting immediate feedback. Figure 2 shows a typical view with the popup window present.

Figure 2. Testbed 3D View with Feedback Popup

The Virtual Warrior uses the APEX advanced game rendering engine. This engine is interoperable with DIS protocols, HLA protocols, and Open Flight database. The underlying simulation used for the scenarios employed with these experiments was the OneSAF Testbed Baseline (OTB). Although the architecture could support multiple players, the scenario was designed to operate with one human Soldier and SAF behaviors for the other team members.

The design of the experimental scenarios with the VW player unit also incorporated the use of the C2 Mobile Intelligent Net-centric Computing System (C2MINCS) into the testbed architecture. This is a dismounted mobile computing platform to provide Soldiers network centric C4ISR connectivity and situational awareness. Specifically for these scenarios C2MINCS was used to send a variety of pre-formatted tactical reports, including spot reports, position reports, and target handoff reports.

DATA COLLECTION REQUIREMENTS

A common thread in training applications with automated evaluation goals, and particularly in ITS systems, is the need to capture as much data as possible to correctly interpret the decision-making of the trainees. Frequently the cognitive skills required for military operations fall into two categories: conceptual knowledge and procedural knowledge. Conceptual knowledge includes general tactical principles and underlying purposes which provide a framework for applying procedural knowledge. For example, conceptual knowledge includes understanding the tactical principles of clearing a building, and the purposes for tasks like submitting reports. Procedural knowledge is the understanding of the specific sequence of subtasks, such as the proper position within a formation in movement. The major categories of data collection requirements for the implementation of automated evaluations for these forms of knowledge in this domain included:

- Simulation entity state data (e.g., position, orientation, posture, head orientation)
- Operator inputs (e.g., reports sent, vehicle mount/dismount actions, use of controls)
- Line-of-sight data (e.g., calculations for pairs of positions)
- Terrain feature data (e.g., coordinates that lie inside buildings)

This data is consumed in evaluation mechanisms defined in a Behavior Transition Network (BTN) format. The notion of underlying forms of knowledge or skills has a counterpart in a hierarchy of principles defined for the domain by the scenario author. In run-time, individual BTNs may perform evaluation functions for either single or multiple principles, depending on whether efficiencies of scale can be realized in terms of data analysis. For example, in a case where two tactical principles would be evaluated via analysis of the same set of source data, then both can be implemented together in the same BTN, even if it produces different conclusions with respect to the different principles in different execution states.

For a simple example of the data required by a specific evaluation principle, consider the task of evaluating for a designated team member maintaining proper position within a fire team formation during movement. Figure 3 below shows a proper wedge formation for a four person fire team.

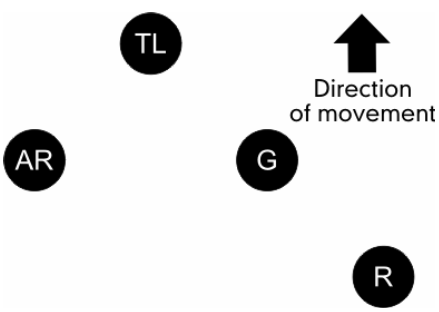

Figure 3. 4-person Fireteam Wedge Formation

For illustration, this example describes a simplified tiered logic that evaluates team member R for proper execution during free-play execution. In the first tier, the evaluation must know when it applies, or more specifically, when the fire team *intends* to be moving in wedge formation. There are many ways to establish this, but a simple method is to simply annotate the terrain. The second tier of the evaluation involves a simple check for relative distance between R and G, without any concern for the positions of other team members, as shown in Figure 4.

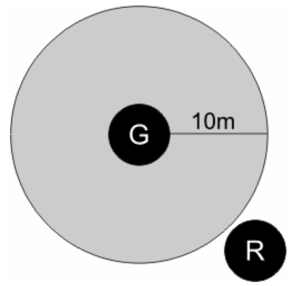

Figure 4. Distance Evaluation

If R is greater than 10m from G, in any direction, then error conditions have been met, and the evaluation triggers a feedback. In Figure 4, R is out of position, being too far from G. However, if this test is passed, then the third tier of the logic is queued. On the assumption that R is within the proper distance radius of G, the next step is to check if R is in the proper section of that radius (area A in Figure 5).

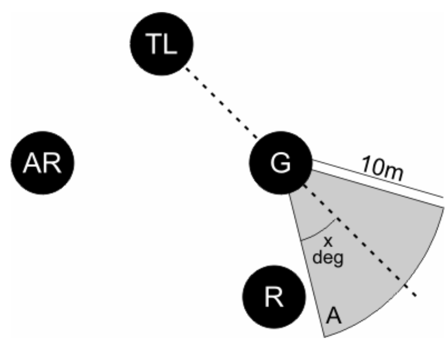

Figure 5. Distance and Position Evaluation

Area A is defined by taking the heading from G to TL, and calculating the space of a pie wedge created by an offset on either side of that heading. In the figure above, R is in a position that would satisfy the second tier test (position within the 10m radius), but fail the third tier test (position outside of area A).

This example contains several simplifications from real-world tactical concepts, and also depends on a specific artifact of how this evaluation would be used in training – namely that the position of G relative to the team leader TL will always be correct because all other entities are controlled by SAF. However, it is useful for illustrating two things. First, data requirements can be simplified with respect to operational definitions based on tactics, techniques and procedures, when the range of use cases establishes constraints that reduce the space of possible interpretations. In the above example, it's not necessary to get an explicit datum for the direction of movement, because this is derived from the SAF positions and movement. Second, the tiered implementation is useful not only for simplifying processing (i.e., when the second tier test is failed, it's not necessary to perform the third tier test), but also for identifying nuances of the conditions in which feedback conditions occurred. Although the same operational principle is violated with a failure of either the second or third tier tests, by distinguishing the conditions in the BTN implementation it becomes possible to generate different (and therefore more informative) feedback content in the two cases. Finally, once the BTN for such a principle is implemented, it can be easily parameterized and abstracted for rapid instantiation in any scenario requiring the same evaluation capability, assuming the same constraints apply.

SCENARIO AUTHORING REQUIREMENTS

One of the focuses of this research was to define the requirements and capabilities for authoring tools that would allow a subject matter expert or other scenario author to construct the training situations where the desired skills and tasks will be exercised. Scenario development involves the choice of locations, placement of entities and routes, and definition of opposing force behaviors to make the scenario "play" as intended for a given set of training objectives. This can be a difficult process if available tools require the scenario to be defined in a 2D environment such as the OTB simulation itself, while the trainee experience is largely in the 3D visualization environment. As a result, the scenario author must be familiar with both tools, and must be able to cross-reference any desired locations in the 3D world with the 2D world where they will be saved. In addition, the scenario author must also think about which evaluations should apply, along with any input parameters they require, and this must again be cross-referenced in both worlds.

Therefore, in addition to the implementation of the training architecture integrated with the VW testbed, a preliminary prototype authoring tool was developed as a platform from which to identify the technical challenges and functional requirements for a usable toolset. This prototype was built on top of the 3D Mission Planner environment provided by General Dynamics, for its compatibility with the Virtual Warrior player unit. Figure 6 shows the main view of the authoring tool.

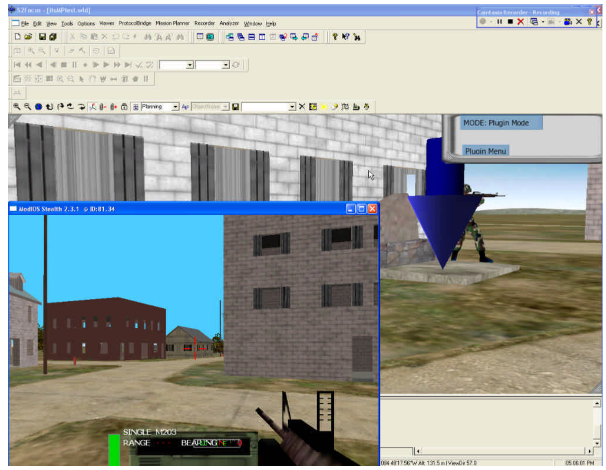

Figure 6. Dismount View from Point of Interest

In this view, a point of interest has been placed in the 3D environment, and a dismounted entity has been placed as well, acting as a form of avatar. Navigating in the environment, the author can see both the location of the dismounted entity from an offset camera position, and the view from the perspective of the entity. This is helpful for constructing contact points in the scenario. A second view is shown in Figure 7, to illustrate the process of applying an evaluation to the scenario.

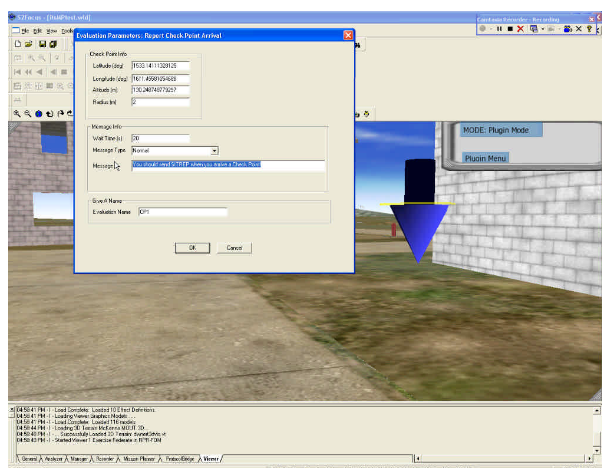

Figure 7. Applying an Evaluation to the Scenario

Since an Intelligent Structured Trainer uses automated evaluations based on ITS technology, flexible application to different scenarios relies on the flexibility of available evaluation mechanisms. For the evaluations constructed with this prototype, their representations were abstracted such that the process of instantiating them for a specific scenario is a matter of filling in parameters, as opposed to constructing similar logic for each scenario. Typical parameters include specific coordinates or areas in the virtual space, named entities or objects, routes or points of interest, and specific values governing the application of the evaluation itself. Figure 7 shows the instantiation of an evaluation for the principle of reporting position upon arrival at a checkpoint. The location parameters are automatically taken from the point placed in 3D, and additional parameters for the evaluation itself establish the delay before feedback should be produced. The evaluation dialog also allows the author to edit the feedback text that will be generated.

Generalizing from this example, the design of the training approach necessitates a model where automated evaluations are constructed in a manner such that they can automatically adapt themselves to a range of scenarios for the domain, including those not yet defined. A framework is necessary so that the scenario authoring process can refer directly to automated evaluations defined for the domain. This is largely accomplished with the organization of evaluation behaviors in a modular structure as individual BTNs that can be simply instantiated with a given scenario.

Through the process of developing the initial prototype authoring tool and reviewing how it could be used for different kinds of scenarios and sets of evaluations, the following observations were collected:

- It's important to use a visualization tool as the backbone for the authoring tool, so that the scenario author can easily fly through terrain to pick locations directly in the 3D view, and have the locations automatically collected and saved in a scenario file. This affords the scenario author with the ability to see positions and sightlines as the training audience will see them as they encounter routes, terrain objects, and vehicles in the scenario execution. The result is a direct procedure for defining the "gameplay" of a scenario without requiring trial and error toggling between the 2D and 3D components of the testbed.

- The ideal authoring tool use case does not require connectivity to the specific simulation component of the testbed architecture. This reduces the installed profile necessary for a scenario author to be productive and reduces the requirement to perform authoring in the same development environment as the testbed.

- The tool must provide the means to easily correlate artifacts of the scenario with the input parameters of any applicable evaluations which require such inputs. For example, after designating control points along a route in the 2D and 3D view of this tool, the author should be able to easily cross-reference a "Follow route" evaluation with these control points with a quick sequence of mouseclicks.

- One of the upfront requirements for such a toolset is the development of a library of evaluations for the training domain, representing a superset of evaluations across anticipated scenarios. This initial overhead will typically payoff when the requirement is to develop a plurality of scenarios.

- When separate components of a training testbed run on different terrain databases, this can result in problems if they're not carefully correlated. This problem can be especially pronounced in digital urban terrain, where there is a significant difference between being *inside* a building versus *outside*.

- The representational format used to capture scenario authoring data is another technical challenge meriting future attention. For example, the representational format for OTB scenarios does not contain any means for capturing ITS-related data such as which evaluations apply with the scenario, and with what parameters. Ideally a unified, generalized format would be developed which could accommodate traditional forms of scenario data in tandem with data supporting structured training.

USER FEEDBACK

A key goal for the research effort was to collect feedback from human test Participants using the VW testbed with the integrated Intelligent Structured Trainer. An experiment was conducted with a specific scenario and set of learning objectives, and used as a basis on which to elicit feedback on usability, suitability, and effectiveness.

Experimental Design

The scenario created for this experiment is based on relevant activities encountered in the Contemporary Operating Environment (COE). Standards for the tasks were derived from the appropriate doctrinal documents and provided as inputs for the implementation of the Intelligent Structured Training architecture. The scenario was then executed by Soldiers to determine if the tasks trained accurately represented the proper concepts and skills, elicit suggestions for additional tasks that could be included, and collect comments concerning operating in the virtual environment.

The training tasks are primarily individual tasks which the Soldier must accomplish for the collective task to be successful. The dismounted Intelligent Structured Training system evaluates three primary individual tasks. Soldiers must be able to:

- Move as a member of a fire team
- Send reports as appropriate
- Perform movement techniques during the collective task of entering and clearing rooms.

Each of these tasks involves subtasks to be executed at different times and locations in the virtual scenario. For the collective task, the trainer prompts the Soldier on his individual actions within the task. The standards for the task include the evaluated individual observing the proper sector of fire during movement, position in the formation, dispersion in the formation, and maintaining contact with the fire team leader. All of these sub-tasks are critical components to successful completion of the larger task. Figure 8 shows a run-time example of feedback displayed for observing the proper sector of fire as part of *Move as a Member of the Fire team*.

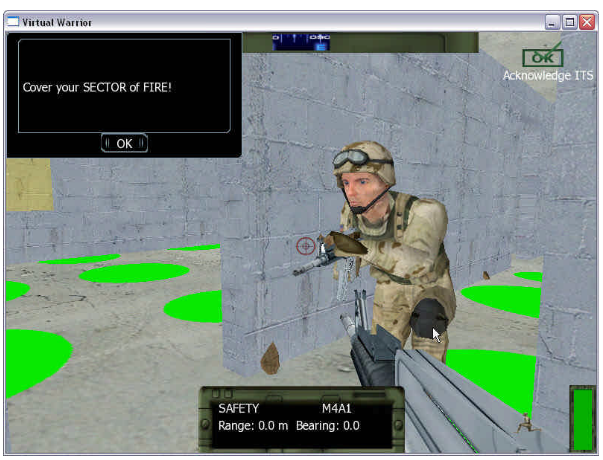

Figure 8. Trainer Feedback for Covering the Proper Sector of Fire

Figure 9 shows example feedback for sending an observation report at the proper time, determined from the fact that the enemy vehicle is within the field of view, and therefore the corresponding report should have been sent.

Figure 9. Trainer Feedback for Sending an Observation Report

For the experiments conducted, all test Participants held an Infantry Military Occupational Specialty, with previous training in the tasks involved in the scenario. Nearly half had combat experience performing the tasks involved in the scenario. Test Participants received a block of instruction on the use of the dismounted Infantry system. They were given time to wear the system and acclimatize themselves to the display, weapons mounted controls, and vest mounted controls. The Participants were also allowed to move about the virtual world to further increase their comfort level. Immediately following the preparatory training period, the Participants were given a standard mission brief using the mission planning tool with the software. After the mission brief, Participants executed in the virtual world for 30 minutes. Each subject completed as many iterations of the scenario as possible within the 30 minutes. Upon completion of the iterations, the Participants then answered a required survey.

The user survey is organized into five sections. Section one contained general questions covering rank, service, combat experience, and familiarity of the tasks conducted in the scenario. Section two consisted of questions pertaining to their assessment of the training system. The Participants were asked to indicate their perceptions of the effectiveness of the trainer as a tool for accomplishing training objectives. Section three contained questions pertaining to their evaluation of the testbed and whether or not it allowed them to accomplish the required tasks virtually. Section three also included questions concerning realism. The Participants were asked a variety of questions concerning training value, weapons effects, and the ability of the directive feedback to focus the attention of the subject. Section four consisted of the subject ranking a list of potential avenues for development in building additional training tasks and modifying the design of the system. Section five of the survey contained a set of questions concerning the individual's response to operating in the virtual world.

Summary of User Feedback

The intent of the assessment of the structured training messages was to determine if the translation of the standard for the task from the appropriate doctrinal material to the software implementation was a realistic interpretation of the published standard. The data gathered from the Participants provides their assessment of the instructional aid to evaluate the performance of the task. The tasks or subtasks that were rated the most favorably were the subtasks of *Enter and Clear a Room,* specifically *Maintaining Sector of Fire in the Room* and *Maintaining Muzzle Awareness*. The subtasks were rated much higher than the parent task of *Enter and Clear a Room*. This suggests that it may be generally easier to construct effective training with lower level isolated tasks in a virtual platform, as compared to parent-level inclusive tasks.

A similar contrast was observed when comparing responses regarding the parent task *Move as a Member of a Fire Team* with those for the subtask *Maintain Sector of Fire During Movement*. A possible source of this rating is the use of the C2MINCS system at the start of the mission. The Participants were instructed to report to the higher unit headquarters when the mission began. The act of sending the report often caused Participants to lag behind the unit in the virtual exercise. This therefore caused difficulty in their conduct of the *Move as a Member of a Fire team* task.

The lowest rated tasks were *Enter and Clear a Room* and *Move as a Member of a Fire Team.* All of the tasks with lowest ratings were tasks that required the subject to operate in conjunction with SAF entities to meet the required standard. The SAF forces can be difficult to work with, and the majority of the Soldiers voiced displeasure with trying to accomplish their mission with the SAF entities. Representative comments about the difficulty of working with the SAF follow:

- "The SAF move too fast in the scenario. I have little time to report before I get left behind."
- "There is no way for me to communicate with the SAF"
- "The SAF behavior is erratic, they are not consistent from iteration to iteration"
- "The SAF do not follow a logical movement pattern to the target building."

This indicates a clear shortcoming either in the implementation of SAF behaviors for the scenario, or in the raw capabilities of the SAF given the constraints of the OTB simulation. A common challenge with virtual dismounted training is that existing SAF capabilities may be insufficient to support the operational complexity required in a training exercise. The prominence of user feedback on topics rooted in SAF-related performance also highlights the manner in which such issues can interfere with the primary training objectives.

Test Participants also made several comments dealing with exposure as a training focus. In an urban fight, it is extremely easy for a Soldier to become exposed to the enemy. In the process of clearing a room, Soldiers become fixated on the threat and often disregard windows and doors to adjacent rooms. Shot placement was the second highest ranked item for future embedded training. This would allow Soldiers to receive feedback instantly on their shot placement. It should be noted that this strong desire for training on shot placement may be an aberration due to the lack of feedback from the SAF enemy entities in the implementation used in these experiments. They were able to absorb at least 10 rounds to the body before becoming neutralized. The only way to achieve instant incapacitation with the SAF enemy entities was to score a head shot.

During the scenario development stage, the initial force structure for the mission followed the doctrinal template required for such a mission. Much of the force structure had to be chopped due to erratic behavior of the SAF entities in OTB. To achieve a minimally smooth level of interaction between SAF entities and live players, some realism was compromised. Most of the Participants were wary of using the technology of the system to accomplish their training goals versus using the tried and true live training methods. Most stated that the technology needed to grow, and they would like to have interacted with live players in their team. Weapons effects are also an area that needed improvement. The sounds from rifles and carbines lacked a realistic sound, and as stated earlier SAF entities (dismounted Infantry) could absorb an inordinate number of hits with little effect.

With regard to the usability of the player unit, the majority of the system was rated favorably. The lowest rated functions were the ability to move within buildings, the location of pop-up messages, the use of joystick and mouse simultaneously, and the use of the C2MINCS for reporting tactical messages. Moving within buildings was primarily a fidelity issue. Certain buildings within the database had glitches that made it almost impossible to identify corridors for movement. This problem generally presented itself in stairwells or narrow hallways.

The use of the joystick and mouse simultaneously could be a workload issue for the participants. It also required the Soldier to violate sound tactical judgment. In order to use the mouse, the Soldier must remove his firing hand from the weapon due to the non-firing hand controlling locomotion. This is unnatural activity and generally caused difficulty for the participants. Difficulty with use of the C2MINCS could also be a workload issue. This was identified in the development stage of this program, and several modifications were made to make sending reports easier. The issue is that once the C2MINCS system is employed, the focus is on sending the required report, and not moving with the unit. By the time the Soldier has sent the report he is already receiving messages admonishing him for failing to meet standards for the movement tasks.

The Participants were given a list of five items for possible modification in future updated versions of the testbed, to facilitate usability for training. These items were locomotion, head mounted display, joystick, mouse, and the format of digital reports. The Participants were asked to rank these items numerically in the order of their need to be modified. Locomotion was the top ranked choice for needed modification. This modification would be the most difficult issue to implement, while still meeting the requirements of an embedded training system. Any device used for locomotion must be small and require minimal accessories to use. The Army has a vision for embedded devices to be used as mission planning and rehearsal tools for combat operations. If the devices associated with the dismounted systems interfere with a unit's ability to carry the required tools for combat, those devices will not be deployed with the unit.

CONCLUSIONS AND THE WAY FORWARD

From a technical perspective, a primary finding from the development and integration effort is a refined insight into the nature of the data needed to implement automated evaluation mechanisms for a cross-section of dismounted operational tasks. Likewise, the development of the test scenarios and initial scenario authoring tool provided a view of the key requirements for effective training scenarios. This helps not only for designing tools to streamline the authoring process, but also for noting the relationship between the task content of a training scenario and the functional ability of available software and hardware to exercise tasks effectively.

In addition to the technical findings from the integration and development effort, the most important finding from the user feedback was the degree to which the usability and suitability of the training environment are prerequisites for effectively executing training functionality. Key performance factors include the SAF ability to interact with the trainee in the performance of operational tasks, and the degree to which tasks can be performed within the virtual environment where they are afforded the opportunity to properly demonstrate proficiency.

For the benefit of future research, it's noteworthy that this study was limited primarily in the number of qualified personnel to undergo testing. The typical operational tempo of units makes it difficult for a unit to conduct a study such as this during training time, which is always limited. This led to the significant role of SAF entities in the scenario. The SAF entities could not communicate with the individual nor reliably vary their course of action based on enemy influences. The main lesson learned with testing and experimentation would be to include three additional Participants to round out the fire team in the virtual environment. This would have provided a better test environment and allowed more communication among team members. By comparison, Michael Woodman, in his dissertation *Cognitive Training Transfer using a Personal Computer-Based Game: A Close Quarters Battle Case Study* (Woodman, 2006), achieved more effective training results when he organized his Participants to interact with three experts in the experiment. The only change from each experiment run was the subject.

Additionally, future work that focuses on building highly correlated terrain databases for virtual urban operations will have a measurably positive impact on the feasibility of virtual dismounted training. The challenge of supporting training-related data with scenario data will also be increasingly met by the development of more flexible representational formats. Specifically, current development work with more modern SAF, such as the OneSAF Objective System (OOS) is focusing on more generalized forms of scenario data and formats that can accommodate scenario data needed by a wider range of federated components.

Intelligent structured training for this exercise was generally specific to the scenario, requiring Participants to operate in a specific area. Although methods were explored from a design perspective for generalizing evaluation mechanisms for application both in varying situations within a scenario and across scenarios, this level of abstraction remains a goal for future research. Future applications could include other dismounted virtual simulator concepts like workstations and CAVEs. The concept for future versions of the structured trainer will allow the trainer to select the area of operation, select the tasks to be evaluated, and then select the personnel to be evaluated. This process needs to be simple and require little additional training if the capability is going to be available at the unit level. Further development on the scenario authoring tools and associated methods will also increase the value of this program, to support training more operational tasks in more situations.

ACKNOWLEDGEMENTS

This research was sponsored by the US Army Research, Development and Engineering Command, Simulation and Training Technology Center. The domain expertise of Major Jason Sims provided a major benefit for the collaborative system development between Stottler Henke Associates, General Dynamics, and the University of Central Florida's Institute for Simulation and Training.

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