Enhancing Human Effectiveness through Embedded Virtual Simulation

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ABSTRACT

Present and anticipated military missions require highly trained and capable military personnel. Military personnel have to be well prepared to effectively and efficiently use state-of-the-art technology under highly complex battlefield conditions. A number of factors are influencing training policies, procedures and technologies. An important factor is the need for units to deploy. This places them in locations where they do not have the facilities and infrastructure needed to optimally plan and rehearse complex missions. Recent advances in computer and display technologies make embedding training and embedded virtual simulation in highly mobile military hardware both practical and effective.

Embedded training is a well-known concept, which tightly integrates training functionality into operational equipment. It allows military personnel to train and rehearse while deployed to an operational area. Embedding training allows skills to be maintained and developed close to the battlefield or during transit. In the past, embedded training has been successfully applied by armed forces primarily for large computer controlled systems such as air defense, and ships. The recent development in areas like Virtual Reality (VR) and Augmented Reality (AR), technologies for virtual simulation and intelligent tutoring systems significantly enlarges the area of application to ground and air forces. The human-centered design and integration of embedded virtual simulation (EVS) technologies covers a broad spectrum, which includes questions in operational user requirements, in training management as well as innovative technologies for the human interface and a possible application of intelligent agents. This paper will present some new successful applications of embedded virtual simulation in ground and air applications. It will refer to relevant aspects of the topic from a training perspective and summarize the results that were achieved during the three year operation of a NATO research study group (HFM-165) on enhancing human effectiveness though embedded virtual simulation. Based on these findings future directions towards the future development of EVS will be presented.

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INTRODUCTION

Highly trained and capable military personnel will always be a core factor for a successful mission accomplishment. This is especially true for joint and combined operations of coalition forces which encounter the full-spectrum of situations in worldwide operation.

Units deploying to face new world situations will likely have little or no time for preparation and they will have to be able to adapt to evolving situations once they arrive. Preparing for this eventuality is likely to become a major requirement for future training policies. Deployed Warfighters will find themselves in locations where they do not have the facilities and infrastructure needed to train for, plan, and rehearse complex missions. Integrating training functionality into a broad range of operational equipment would allow forces to take a training capability with them when they deploy. This concept is subsumed by the term "Embedded Training" (ET).

At the unit level, ET enables training of the full mission cycle with more realism than with conventional training systems or operational equipment alone. ET reduces the need to mimic adversary assets with 'role playing' live assets, and reduces the high costs for equipment, logistics, planning and personnel imposed by the use of instrumented ranges. So far, for the most part ET has been limited to large systems where space, weight and power requirements are not an issue, e.g., patriot missile and aegis c2-systems. For these same reasons incorporating ET into ground and air vehicles has been more of a challenge.

ET concepts are not new. Twenty-five years ago the United States Army's Vice Chief of Staff and the civilian acquisition executive wrote a joint letter to the Army's materiel acquisition community that established a policy requiring materiel developers to consider embedded training as the preferred alternative for system training. The policy also required material developers to justify why embedded training was not viable before choosing other training delivery options (Thurman & Ambrose, 1987). During the late 1980s, the U.S. Army Research Institute produced a ten volume guide on how to implement ET in Army systems (Finley et al., 1988). Topics covered included development of ET concepts (Roth, 1988) and requirements (Roth, 1988), integrating ET into the prime system (Evans & Cherry, 1988), incorporating ET into unit training (Strasel et al., 1988) and logistics implications (Cherry et al., 1988). The overview volume contained the following definition of embedded training:

"ET is defined as that training which results from features incorporated into the end item of equipment to provide training and practice using that end item equipment. … The feature(s) MUST include stimuli necessary to support training: they should include: performance assessment capability, appropriate feedback, and record keeping." (Finley et al., 1988)

The definition discussed three different types of ET:

- Fully embedded: ET is completely embedded within the system configuration by software application or a combination of both software and system configuration.

It requires the end item of equipment to have been designed with ET as part of its system architecture.
- Strap on: ET may be executed by some kind of strap on (e.g., a video disc player) or plug in equipment. It can sometimes be added at a later point in design
- Umbilical: ET is a mixture of embedded and appended components. It can also be added at a later point in design.

A recent vision for ET written by the office of the U.S. Army's Project Manager for Training Devices (PM, TRADE) stated that ET minimizes the artificialities of combat training by maximizing the use of real combat equipment. The vision statement stated that ET will:

- Enable training while Soldiers are deployed.
- Facilitate mission rehearsal without the need for special equipment.
- Increase utility of existing combat equipment and save money by giving equipment both a combat and training function.
- Rapidly disseminate combat experience, cultural landscape awareness and, tactical adaptations, and the latest intelligence through training in the war zone, and
- Support home station training by bringing training opportunities to locations that traditionally are not equipped for training or do not have the space for combat maneuver.

There have been many implementations of ET. In their review of embedded training utility, Morrison and Orlansky (1997) found 56 systems that incorporated, or planned to incorporate, embedded training capabilities across the U.S. Army, Navy, Air Force and joint service community. As noted above, most of the time ET was included in relatively large military systems.

Recent miniaturization of electronics and computer components along with their increased capabilities has reduced the need to off load training system components making embedded training a more viable option for (smaller) combat vehicles and aircraft. Furthermore, state-of-the-art virtual simulation technology, e.g., Virtual Reality (VR) and Augmented Reality (AR) facilitates integration of virtual simulation into operational equipment. Embedded Virtual Simulation (EVS) significantly enlarges the potential application of ET within ground and air forces.

Still, modern systems designed to incorporate EVS can have a mixture of fully embedded, strap on or appended components. The definition of EVS adopted by the NATO Human Factors and Medical Panel (HFM) Research Study Group 165, whose findings are summarized in this article, is:

"Embedded Virtual Simulation is an enabling technology that provides an interface to interactive simulations that reside within or are appended to the operational equipment. It can provide links to local and/or geographically distant trainees and instructional resources. It enables a full range of capabilities for aiding, learning and practicing individual and team knowledge and skills."

Examples for current implementations of EVS

A good example of implementing EVS in a ground combat vehicle is the German Puma infantry fighting vehicle. Within the PUMA many of the components used for operating the vehicle also are used in training. The image generator which produces the visual virtual environment for training is in effect an appended component since it is loaded onto the rear of the carrier and occupies the seating area normally occupied by an infantryman (Schmidt, 2010).

The United States Army's Future Combat System (FCS) was to have an embedded virtual training system which had much of the same functionality as the U.S. Army's Close Combat Tactical Trainer. It would have also incorporated interactive multimedia instruction capability, a training management system, and the capability to interact with engagement simulation systems (Shiflett, 2010). The cancellation of this system was a major blow to policies requiring ET in new combat systems.

In aerospace, the Royal Netherlands Air Force has demonstrated its potential and technical feasibility in an F-16 fighter aircraft (Krijn & Wedzinga, 2004). The EVS application is called ECATS (Embedded Combat Aircraft Training System). It provides pilots the capability to train against virtual threats that are generated by a constructive scenario simulation capability embedded on-board the aircraft. ECATS provides both virtual air and surface threats, is not dependent on range equipment, and can be implemented as a pod or completely integrated into the aircraft mission system.

Relevant aspects for EVS

A successful implementation of EVS for different platforms has to follow a comprehensive, system-oriented approach. It should not be limited to purely technical questions and solutions. EVS has to go one step further and address open questions in the field of operational user requirements, training management, the human interface, and, finally, intelligent tutoring systems. These aspects are described in the following sections.

Interviews with a broad spectrum of potential users identified different operational requirements. They addressed open questions for training design, special operational needs and general requirements for user interaction and team training.

OPERATIONAL USER REQUIREMENTS

An analysis of operational user requirements must identify all the potential users of an EVS system. Users include not only trainees, but also supervisors, instructors and other personnel involved in training. The needs of each of these categories of users must be addressed in the user requirements within the context of the training requirements and content the EVS system will present. EVS may provide a high fidelity tactical training and rehearsal environment that includes challenging training scenarios with an optimal number of learning events and threat training. However, data recording, after action review, scenario generation, and training management requirements must be addressed to create a training system that can be used anywhere, anytime and significantly increase the effectiveness of training time for the trainees.

A new training design methodology was developed specifically for simulation-based training (Farmer et al., 1999). It takes mission characteristics, task analysis, analysis of trainees / target groups and training objectives into account in development of training requirements. However, since application of EVS is different from the use of traditional training media, traditional training analysis methods may not be satisfactorily applicable to EVS requirements. To take full advantage may require a rethinking of our current approach to the training pipeline.

Instead, we make an attempt to classify military user requirements under three headings: (1) user interaction requirements, (2) training management requirements, and (3) affordability requirements.

User interaction requirements

The level of realism of the training environment is one of the key issues for a successful transfer of this training to the real environments, i.e. battlefields or war zone. For this, the training environment and the real environment have to share relevant common characteristics and properties. The environment in which a full mission scenario is practiced generally needs more realism than an environment in which only the control of a piece of equipment needs to be trained. Realism is not limited to visual realism but also includes perception of self-motion, haptic feedback and consistency of multi-modal stimuli. While legacy training simulators may be based on application of virtual simulation techniques, EVS will more likely rely on the application of *augmented* reality techniques to provide a live direct or an indirect view of the physical, real-world environment whose elements are augmented by computer-generated sensory input, such as sound or graphics.

The perceived realism of the environment also depends on the behavior of synthetic entities in the EVS. Such intelligent CGFs or Non-Player Characters (NPCs) represent real people or weapon systems including their behaviors and cognitive states (e.g., decision-making capabilities). CGFs are fully automated representations of friends, adversaries, or neutral ‘characters’. Most behavior of CGFs in EVS will be far from trivial. For example, real enemies are, at least to some extent, unpredictable. They seek to maneuver themselves into a better position as the tactical situation changes. They react to friend and foe. They are adaptable. In other words, they are smart. The smart element in the behavior of these virtual opponents involves a number of factors. For instance, they should be able to detect and identify targets to attack, but should also be capable of defending themselves against enemy action.

Many weapon platforms are operated by teams, and platforms operate with other platforms in many missions. Obviously, team training is an important area of application for EVS. Human interface requirements need to allow co-ordination among team members and platforms. This may require dedicated communication channels. The use of EVS for team training could promote unity in operational procedures and doctrines and help train effective communication techniques. Training scenarios could, inter alia, be based on actual battlefield incidents involving factors related to teamwork.

It is also obvious that the usability of an EVS system has to be considered appropriately. Among other issues, usability addresses the general ease of use and learnability of the system. It is important that usability has to consider characteristics of the different users, such as trainees, supervisors and instructors). Usability involves the consideration of different issues, e.g., learnability, efficiency, memorability error and satisfaction (Shneiderman, 1980; Nielsen, 1994).

Safety is another critical operational issue with EVS, because a main idea is the use of operational equipment. Therefore, it is important that some functionality (e.g. firing a gun, ground moving) has to be disabled in training mode. Moreover, it should be clear to the trainee when the training mode is engaged. Critical maneuvers for airplanes have to be avoided to prevent health hazards and possible accidents. This aspect contradicts the idea of training very close to reality to some extent, but it is essential for safety of the trainee and others in the training environment.

It is obvious that the operational requirements address a broad scope of issues that have to be addressed and handled by an EVS system. Following a top-down approach, it should to begin with an analysis of training management and the inclusion of EVS into existing training designs.

TRAINING MANAGEMENT

Training management is the continuous process used in an operational unit, to develop, implement, deliver, evaluate and improve training programs. The goal of training management is to optimize the available resources, materials, guidance, and time to meet specific training requirements. Relevant functions of training management for EVS are identification of training needs, design of EVS scenarios and planning of EVS exercises, managing briefing, after-action review, data collection and training evaluation.

EVS is characterized by a level of realism. This requires management of highly realistic training scenarios. The scenarios are also closely connected to training objectives. For an effective scenario management it should be possible to script events. EVS designers should also allow trainers to integrate new scenarios into the exiting set of scenarios to enable training just in time.

To effectively measure and interpret trainee performance, an EVS system has to do this onboard in order to estimate training effectiveness and provide feedback. Automatic capturing and keeping track of trainee performance allows optimal management of subsequent training sessions. Intelligent tutoring systems can facilitate training management by reducing total training time required without requiring additional instructor time.

Providing instructions and feedback is another important factor for all types of training. Consequently, an EVS system has to include mechanisms for feedback as well. It can be provided by an on-board system or off-board. In the first case feedback may be provided by the operational display or by additional devices. In the second case the system requires an additional fast, versatile network to an instructor's station. A further alternative would be direct feedback by an instructor or an intelligent tutoring system. This aspect will be handled in a subsequent section of this paper.

Functions and competencies of senior personnel

Because the EVS is embedded in - or appended to - real equipment (e.g. to an aircraft, ship or vehicle), ET typically does not have a human instructor in the classical sense. The instructor function in virtually-based EVS is most often performed by an embedded instructor which resides in software. In some cases there is no instructor function and the trainee must learn from whatever feedback the EVS provides in an unorganized manner. In those cases the trainees must function as their own instructor. In most cases, while there is not a human instructor in the traditional sense in EVS, there will need to be a senior person who can perform some of the training management functions a traditional instructor would perform.

There are different competencies necessary for instructors, training managers and training evaluators.

The instructor's competencies include

- Communicates effectively,
- Plans and prepares,
- Uses instructional methods and strategies,
- Assesses and evaluates,
- Manages.

The training manager's competencies are

- Communicates effectively,
- Designs and develops,
- Assesses and evaluates,
- Administers.

And, finally, the training evaluator's competencies require:

- Communicates effectively,
- Implements an evaluation plan,
- Manages the evaluation.

In addition to these three players, management of an EVS often includes a supervisor, who

- Provides additional feedback,
- Remediates prescriptions,
- Keeps records,
- Plans the training pass forward for the trainee,
- Reports individual and aggregate progress up the chain of command,
- Determines if the trainee is ready for operations on their weapon system.

Instructional strategies for EVS

The identification of suitable instructional strategies for EVS is a matter of applying a methodology such as Instructional System Design or Training Analysis (see e.g. Farmer et al., 1999). A simple instructional strategy confronts the trainee with a scenario (Scenario Based Training) using EVS, i.e. involving some degree of simulation.

Additional instructional strategies that were mentioned are: whole-task training with injection of virtual entities into the training scenario, instructional strategies based on intelligent tutoring (replacing the human instructor), instruction strategies that are based on remotely monitoring of the exercise and providing instructor feedback via radio (e.g. emphasize training), adaptive training, in which parameters of the training environment (level of complexity, speed, etc.) will change depending on progress of the trainee. Depending on the nature of the 'host equipment' on which the EVS is implemented (which may range from a handgun to complex systems like sonar devices onboard navy vessels), the instructional strategy may be based on part-task training (e.g individual training of marksmanship) with any combination of part-tasks, with or without the whole-task context or may be based on whole-task training in the operational environment (e.g. team training of fire fighting on a ship).

The strategy of an EVS system also defines the context of its training application. The human interface, which is the front-end of the system, has to be designed according to this context and take user characteristics and capabilities, as well as user experience into equal account.

THE HUMAN INTERFACE

An EVS system has to consider that experiencing a realistic environment is multi modal. The human interface to the EVS could stimulate several human senses at the same time to promote the perception of immersion within the virtual scenario. This effect could be achieved or enhanced with sensors and controls that allow self-directed movement within the spatial environment, gestures and natural real-time interactions, including spoken interactions, with animated virtual characters or avatars. Recent and emerging technologies now provide opportunities for enhancing the uses and efficacy of EVS systems.

For all types of systems, concerns about weight, size, and safety, as well as technological constraints were found to restrict the design and use of the human interface to an EVS system. For example, the cues of physical motion are limited with embedded training in a tank because it could be unsafe if movements of the vehicle are unrestricted during an exercise. In an ideal EVS implementation, the user will not be able to tell the difference between the real and simulated environment. Thus, it will be unclear to the user if a failure is real or simulated and a part of the exercise. Unlike traditional simulation, EVS needs to include a method to remind the soldier whether the weapon system is in training or operational mode.

Many weapon platforms are operated by teams, and those platforms most often perform their missions with other platforms. Obviously, team training is an important area of application for EVS. Human Interface requirements need to allow co-ordination among team members and platforms. This may require dedicated communication channels. The use of EVS for team training could promote unity in operational procedures and doctrines and help train effective communication techniques. Training scenarios that require teamwork could be written based on actual battlefield incidents.

In the future, artificially intelligent agents will likely be deployed with operational equipment to support EVS-based training. These agents will not be restricted to just computer-generated forces. It is envisioned that intelligent tutoring systems and virtual humans will be incorporated in EVS systems to structure, guide, and coach the training audience as well as provide intelligent adversaries and neutrals that can interact on a personal level with soldiers. The human interface to the intelligent agents will include low cost, unobtrusive methods for sensing behaviors (e.g., actions, gestures) and physiology (e.g., heart rate and galvanic skin response). Behaviors and physiology (observable trainee states) will then be used to predict cognitive states (e.g. unobserved trainee states) and tailor the training accordingly.

Cognitive states can either foster or impede learning. Taking them into account in training should contribute to the efficiency of the process. Affective cognitive states such as frustration and confusion can impede learning while attention and engagement can foster it. Methods to accurately predict these cognitive states will determine the adaptability of any computer-based tutor and either limit or enhance the trainee's perception of the tutor's persona, credibility and supportiveness. In other words, the tutor's effectiveness (in terms of learning) is likely to be limited by the acceptance of the artificially intelligent tutor and acceptance (or lack thereof) will be limited the tutor's ability to predict the state of the trainee at least as effectively as a human tutor.

The costs of simulation have long been hypothesized to grow exponentially with fidelity while training transfer has been hypothesized to increase monotonically with fidelity, but with diminishing returns (Miller, 1954). This is the problem facing decision-makers who must decide how much to spend on a simulator, or how much to include in an EVS. The plots of these relationships would be very useful if they were based on actual data but for the most part they reflect opinion and not data. Knowing the relationship between fidelity and training could be used to identify the amount of fidelity that yields the most training value for cost. Unfortunately, there is no objective method for measuring the overall fidelity of a training device or EVS system. There are few studies and many different measures of training transfer. Thus, there is a need to develop measures and to determine their relationships. In addition, subjective opinion, human adaptation and simulator-induced sickness are outcomes that further complicate our understanding of the human factors associated with the design, use and evaluation of EVS.

Although training systems applying virtual simulation or VR are generally less reliant on physical reproductions of the operational equipment than traditional simulators and are much less reliant on the use of operational equipment than EVS (by definition) systems, they are sometimes better suited to specific training objectives than full mission simulators because the human interface of a VR system can be more easily customized to match a particular training objective and its requirements, for example, the presentation of stereoscopic images for making accurate visual judgments of the distance to an object or a surface. Hence, VR is well-suited to part task training, mission planning and mission rehearsal applications where specific, rather than comprehensive, learning objectives can be identified. Since many VR technologies could be used to interface an operator with an EVS system, EVS systems could also provide a better human interface to a simulated environment than traditional simulators, and like VR, EVS systems could sometimes be better suited to part-task training than full task training. Safety concerns, for example, limits on the motion of operational equipment when the EVS systems is in use, or technological limitations, such as the current inability to display simulated targets within visual range of a fighter in the air, will sometimes limit EVS to part-task training. However, the use of VR or EVS systems for part-task training does not necessarily limit the impact that they can have on subsequent task performance since part-task training can be very effective and disruptive when the training they provide is put to use. Consider,, the training needed by the terrorists of 9/11; they had to know how to fly a plane but did not need to know how to take off or land.

EVS systems could also afford significant benefits for mission planning and mission rehearsal since they could allow last minute, just in time training that could take advantage of the latest intelligence data for scenario development, presentation and human interaction. EVS provides a means to minimize human memory decay by closing the gap between learning, mission rehearsal and training transfer to the operational task.

THE APPLICATION OF INTELLIGENT AGENTS

As mentioned briefly earlier, the practical use of EVS may be largely contingent upon the availability of artificially intelligent agents to support interaction (e.g., feedback, and content presentation) with the trainee, manage instructional processes (e.g., assessment of progress toward training objectives), and reduce the number of human role-players need to support effective training in EVS. Intelligent agents are autonomous computer-based processes that observe and act upon an environment and direct their activity towards achieving goals (Russell & Norvig, 2003).

Trainee modeling, pedagogy and expert modeling

It is envisioned that intelligent agents in EVS will observe and act upon information about the trainee and the training environment (see **Figure 1**1).

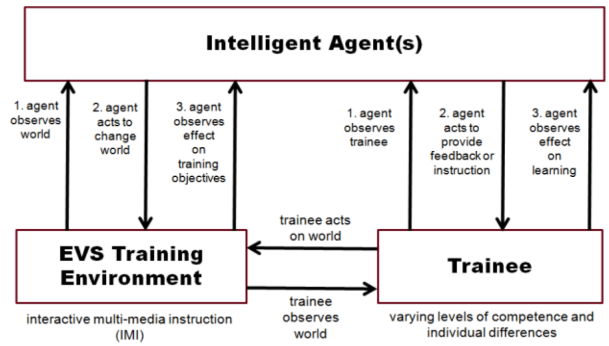

Figure 1: Intelligent Agent Interaction in EVS

Intelligent agents can "observe" trainee behaviors and monitor their physiological responses through commercially-available sensors (e.g., webcams, heart monitors, and electro-dermal activity sensors) that may be used to interpret cognitive or affective state. Sensor data along with past training performance and other competency measures, demographic information, human observations and/or self-reported data can be used to assess the trainee's current "readiness to learn", their current state of knowledge, and determine what further training is needed. This data may also be able to predict their future performance and states.

Morrison & Orlansky (1997) noted that "individualized instruction by embedded tutors, requiring little or no supervision" should be considered as a common feature of embedded training systems. It should be noted that the systems evaluated in this study did not consider physiological sensors, past performance or other inputs to assess the trainee's cognitive and affective states, and therefore were limited in optimizing instructional strategies (e.g., feedback or scenario adaptation). The enhanced capabilities of sensor technologies and machine learning techniques over the last 15 years should mitigate this limitation and should be strongly considered in the design of new EVS.

In addition to assessing the state of knowledge of trainees, intelligent agents within tutoring systems could also be used to determine optimal instructional strategies. Instructional strategies include, but are not limited to: tailoring the pace of instruction, managing the challenge level of instruction, making decisions to increase/decrease the frequency of direction and support, asking questions and pumping trainees for information.

Sottilare (2009 & 2010) asserted that the lack of human tutors within operational platforms limits the understanding of each trainee's cognitive state (e.g., emotional state) and the comprehensiveness of a trainee model within computer-based tutoring systems.

Tutoring technology is not sufficiently mature to provide accurate, portable, affordable, passive, and effective sensing of cognitive states, and therefore lack of interpretation of the trainee's cognitive state limits the adaptability and effectiveness of the instruction in today's embedded training systems, and other computer-based tutor-dependent environments.

There is potential for intelligent agents to supplant painstaking cognitive task analyses used to develop expert models for computer-based tutoring systems (Williams, 1993). Advances in sensor technology (e.g., unobtrusive physiological and behavioral sensors) and machine learning techniques make it possible to produce more expansive and accurate expert models automatically, but additional research is needed to standardize processes and improve the accuracy of these models especially for tasks in ill-defined domains.

EVS intelligent agents as role players

The potential of intelligent agents as role player or non-player characters in EVS is significant and even now a practical option for some tasks. Heuvelink et al. (2009) utilized intelligent agents as non-player characters in a stand-alone low-cost desktop simulation used by a single trainee who played the role of the Officer of the Watch (OW) in shipboard fire fighting training scenarios. The Chief of the Watch (CW), Machinery Control Room Operator (MCRO), Confinement Team Leader (CTL), and the Attack Team Leader (ATL) are all agent-based characters. This allows individuals to train in realistic and complex environments in the absence of other human team members.

Bell & Short (2009) advocated the utility of speech-interactive synthetic teammates for training, mission planning and rehearsal. They identified the following issues with human role-players: many training exercises use trainees as training aids; human role-players introduced unwanted variability into the training; sometimes instructors were also trainees and this complicated performance assessment; and costs for human role-players were recurring (e.g., compensation and transport). Non-player characters were seen as a viable option to overcome these issues. As an example, they created a set of Close Air Support (CAS) scenarios, focusing on dialogue between the pilot and a Joint Terminal Attack Controller (JTAC), which was played by an intelligent agent.

Current limitations of intelligent agents in EVS

An analysis of EVS requirements by the HFM-165 RTG highlighted significant technical challenges in the development and deployment of EVS within operational platforms. Among those challenges were communication and interaction with the trainee to support real-time feedback as well as an after-action review of their performance during embedded training exercises. This involves more than just movement of information to and from the trainee, but also includes intelligent observation. In live simulations, performance data is collected via sensors on an instrumented range and/or by human observers, but the use cases identified by the RTG included deployed scenarios in un-instrumented areas and without specialized observer personnel. The RTG evaluated technology-based solutions and more specifically intelligent agents and their potential. Some unanswered questions remain and are left for future research:

- How should information (e.g., feedback, instructional content…) be provided to the trainee in EVS?
- When (and how often) should feedback be provided in EVS and is it different than in conventional training simulations?
- What level of human involvement is needed in EVS? Can it be a fully automated or semi-automated process?
- What are learning enablers and limitations in EVS?

CONCLUSION AND FUTURE DIRECTIONS

ET has been a promising concept for providing training on combat systems. But technology and cost implications limited ET to training applications with large platforms such as air defense and naval systems. Few systems have implemented ET and those that have failed to go much beyond the capabilities of existing simulators. Among others, one reason for this is that ET has to be able to accomplish the functions that a simulation center staff and instructional infrastructure perform but perform them on-board with the members of the training unit. This goes well beyond requirements for simply incorporating simulation capabilities. It also addresses how training delivery and management functions should occur. One possibility would be incorporating intelligent tutor technology as means for governing what training is delivered to meet training needs.

With the ongoing development in computing performance and new display technologies in the field of virtual simulation, Augmented and Virtual Reality (AR/VR) made ET available smaller platforms such as ground combat vehicles and aircraft. Miniaturization of the technology makes it possible to embed training functionality into smaller platforms. Therefore, project managers and training agencies should reconsider this possibility.

EVS utilizes AR/VR technologies thereby allowing trainees and human operators to experience synthetic training environments utilizing the same equipment and platform as they would in the real world. Ideally trainees would experience the same cues in the synthetic world that they would experience in the real world. They should be able to react to complex synthetic stimuli as if they were real. In this connection, AR/VR provide a technological approach that can provide a realistic training environment and a natural human-system interface by applying new interaction techniques and interface technologies. Their effectiveness depends on human perception, cognition and motor response demands of the tasks to which they are applied. Although AR/VR is capable of accomplishing real time full and part task training that rely primarily on visual perception, research is still needed to help specify the displays and interfaces needed for the other senses. This is especially important for EVS systems, which require minimum load and dimensions. Poor interfaces can lead to negative side effects like physical exhaustion and simulator sickness.

Current representations of virtual environments do not include the “mud and dirt” experiences that soldiers experience in the real world. Therefore, AR/VR technologies can contribute to effective training strategies but they will not totally replace other education and training methods or environments, particularly, live training. While tactics and maneuvers can be performed in VR, soldiers will always need to experience the physical demands and conditions of the real world. Virtual simulation can support the effectiveness of live training with the introduction of AR targets and virtual humans. VR will help prepare soldiers for live training by broadening the spectrum of the situations the soldiers have encountered prior to training on live ranges.

With regard to embedded virtual simulation (EVS), which applies AR/VR technology to embedded training, some of the most mature applications have been in command and control domains. Because the technological development in these areas has led to tremendous advances, EVS will become applicable for naval, ground and air platforms in the near future. There are examples of EVS being a required component of combat systems. Although it was eventually canceled the U.S. Army Future Combat System (FCS) required EVS and had training identified as a key performance parameter. The German Puma infantry fighting vehicle and the F-35 fighter, also explicitly required embedded training in their overall design concepts. EVS is a maturing concept that will be implemented more frequently in the future as technology improves and becomes more affordable.

Compared to platforms, EVS for dismounted Warfighters remain a difficult challenge. This is partly caused by physical restrictions, especially the extra load and energy requirements added by the training system. In addition it would also require new display technologies for augmenting the real-world scenes with computer-generated stimuli and new tracking methods to keep track of the Warfighters position within and outside buildings and other structures.

A continuing challenge in support of all ET but in particular with EVS will be to push for the integration of training technologies into the design of current and future operational platforms. To do this, ET/EVS should be integrated in the system design cycle as early as possible. The alternative, a retrofit of existing platforms with ET/EVS systems, is likely to cause additional technical problems and costs. Since system acquisition designers are often separated from simulation and training designers, a more coordinated approach for the total system design may be needed.

In general, EVS has the potential to maintain the currency of training. As already pointed out above, human-centered design and integration of embedded virtual simulation technologies requires thorough review and analysis at different levels. EVS covers a wide spectrum of human-system integration spanning from novel pedagogical concepts to innovative techniques of human-computer interaction.

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