Web Client Training Solutions in DoD Enterprise Computing Environments

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ABSTRACT

The use of commercial gaming technology by the US military for PC-based training and mission rehearsal applications is increasing. However, deployment of this technology typically requires high-end hardware and large, lengthy software downloads; or worse, deployment via physical media and technical support. Additionally, DoD Information Assurance (IA) requirements forbid the execution of any software that has not been through an arduous certification process. Finally, the services are attempting to standardize computer and networking resources to specifications geared towards typical office applications (e.g., document editing, email, web browsing, etc.). These platforms typically have a multiyear refresh cycle so that any particular computing station could be up to 3 years old. Networking performance is “sized” for office expectations and not interactive content delivery. The push to adopt gaming and simulation platforms for interactive training is running counter to the push to standardize computing and networking platforms across the DoD. Services often cannot afford the costs of deploying additional equipment and resources for gaming and simulation-based training. Web client solutions, interactive applications that work primarily within a web browser environment, run on existing DoD computing and networking assets. The US Air Force and Navy have teamed to achieve a highly interactive web-based mission rehearsal trainer capable of being delivered through the browser on a typical enterprise desktop computer. This paper discusses the requirements, trade-offs and technology researched this year to meet this need.

ABOUT THE AUTHORS

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INTRODUCTION

Computer game technology is enabling a transformation in military training systems. The availability of capable commercial game engines and tools make it possible to create custom simulations that focus on niche operations at significantly lower cost than traditional training simulation projects. Technology and management leaders at the United States (US) Army Program Executive Office for Simulation, Training and Instrumentation (PEO-STRI) are investigating the potential for using game technology to create several hundred unique training systems to serve hundreds of niche military occupational specialties (Smith, 2007). Similarly, the US Navy, Marine Corps and Air Force are also making investments in commercial game technology for training applications.

There is, however, a significant problem associated with using commercial gaming technology for military training: It usually requires the installation of software, or the use of high-end computing hardware, or both. While this business model works for the gaming industry, it is not practical in today's military computing environment for reasons that will be discussed shortly.

Recently, the Air Force Air Staff has been seeking a solution for delivering combat convoy mission rehearsal training in a web browser. This paper discusses the issues, challenges and potential solutions gleaned from the authors' experiences with this project.

THE OPERATING ENVIRONMENT

The standard military office computer imposes certain limitations and constraints upon the application of simulation and gaming technologies.

Seat Management

Several years ago, the military realized the crucial role that office computers play in mission accomplishment and began to treat core networks as weapons systems (Koman, 2006). The pursuit of stable, protected and reliable networks and computers led to enterprise-wide standard information technology approaches such as the Air Force's Standard Desktop Configuration (SDC), the Army Golden Master (AGM), and the Navy/Marine Corps Intranet (NMCI). All of these efforts established software and hardware baselines for military networks, and locked down permissions on individual user systems. At the same time, mass acquisition of computers to support each service has led to good stewardship of taxpayer dollars. These computing platforms are oriented toward business and office productivity uses, and are not optimized for interactive training simulations and games.

Operating System and Software

Standard military office computers currently run Microsoft® Windows XP or Windows Vista® operating systems. Configuration controls imposed by SDC, AGM, and NCMI go far toward reducing vulnerability to malware and operator error. A standard disk image installed on all standard office computers includes the operating system, applications, utilities, plug-ins, and registry policies (security settings). NMCI calls this the *NMCI Core Build Contents*, AGM calls it the *Gold Disk*, and SDC calls it the *Standard Disk Image.* Next are the standard security settings preventing users from doing anything considered a possible security risk, particularly installing software and executing unsigned or untrusted mobile code. This enforces policies against installing software on a machine unless the software is licensed, has undergone the rigorous Certification and Accreditation (C&A) process, and has received risk of use acceptance by the appropriate designated approval authority. Users cannot install software on their assigned system without approval and support from system administrators even if it supports mission requirements. For some services, this can mean a significant additional charge for each seat and has driven military training communities toward compromises. One approach provides unaccredited game-based simulations for use on dedicated computers in either standalone mode or connected with isolated networks. Obtaining accreditation is difficult, expensive, time-consuming, costly, and rarely employed for training applications. The easier (and most common) approach requires settling for drastically degraded visual (2-D instead of 3-D) capabilities supported by the seat managed systems.

Hardware

Standard military office computers are not optimized for state-of-the art interactive simulations and games which often make extensive use of 3-D graphics. Air Force market research concluded that 128MB on-board 3-D graphics and Microsoft DirectX® 9.0 application programming interface support is the minimum requirement to deliver an immersive first-person experience adequate for reinforcing tactics, techniques and procedures at an acceptable cost. Three year-old standard military computers narrowly meet this minimum requirement (USAF, 2008). The lack of hardware vertex shader support on the majority of these machines (including brand new ones) precludes the use of many 3-D game engines or drives developers to perform workarounds. Other limitations include low capacity hard drives, and RAM limited to 512MB on Windows XP-based machines and 1GB on Windows Vista-based machines. Together, these deficiencies thwart access to newer gaming features and prevent use of high-performance training software.

Networks

Traditionally, geographically distributed networked military simulations have required expensive, high-speed, dedicated, secure networks. Even limiting connectivity to dedicated local area networks (LAN) can require significant equipment and technical support to sustain operation. In order to deliver first-person simulation to the warfighter, the system must communicate over the existing military network infrastructure (i.e., Non-Secure Internet Protocol Router Network (NIPRNET)). Constraints include network bandwidth, firewalls and latency. Bandwidth requirements can be minimized by pre-downloading initial data on a per-machine basis or including it with the executable code. The major bandwidth requirement will then be for bidirectional transfer of simulation entity state and voice data. As long as the data pipe is large enough to support the bandwidth requirement, bandwidth will not affect speed. Therefore network latency, the time it takes to send the data to another computer traversing through all the firewalls and switches between the two points before it is processed by the other computer, presents the real challenge.

Information Assurance

The DoD application information assurance (IA) has evolved into a comprehensive certification and accreditation (C&A) process. C&A manages the implementation of IA capabilities and services to assure that software executing on military computers is reliable, supportable, and does not introduce vulnerabilities to the network. DoD Instruction 8510.01 *DoD Information Assurance Certification and Accreditation Process (DIACAP)* dated 28 November 2007, provides guidance for accreditation decisions regarding the operation of DoD information systems, including browser plug-ins, core enterprise services and web services based software systems and applications (DoD, 2007a). The C&A process, required for all newly developed and purchased software modules, is long, involved, and arduous with no guarantee of authority to deploy on operational systems and networks. As mentioned in the Operating System and Software section, these certification processes can cause significant delay and cost for any new applications that require C&A. This can often make the difference between a training project that is achievable and one that has difficulty meeting schedule or cost goals.

TRAINER REQUIREMENTS

The following requirements apply specifically to the Air Force Air Staff convoy effort although they are thought to pertain broadly across other scenario and mission rehearsal training requirements.

Immersive

Three dimensional environments are especially, though not exclusively, adept at producing a sense of "presence" (Lombard & Ditton, 1997) that cognitively places the trainee in a visual simulation of the environment where the mission is to be rehearsed. Specifically, presence is defined as a psychological state of "being there" which is mediated by an environment that engages our senses, captures our attention, and fosters our active involvement. (Witmer et al., 2005) Immersive training systems give the trainee the ability to cognitively rehearse scenarios in a realistic, safe, relatively inexpensive, and engaging environment. Producing immersive training environments that offer a sense of presence is a key goal of these trainers. Initially, the intent is to simulate generic missions in an environment with geo-typical terrain in order to reinforce correct and current doctrine and tactics, techniques, and procedures (TTP).

Learning Management

DoD Instruction 1322.26 *Development, Management, and Delivery of Distributed Learning* released 16 June 2006 specifies that learning management systems (LMS) shall be used to "deliver, track, report on, and manage distributed learning content, learner progress, and learner interactions" in the context of learning objectives. Instructional science professionals point out that for game-based learning to be effective, it should be designed with instructional goals in mind (Hays, 2006, pp 306-313). Air Force convoy rehearsal requirements include the ability to track participation in tutorials, including quiz scores and items missed, and the ability to track numbers of missions performed by mission type and scores for each session. Raw score requirements include sector scanning, speed/intervals, mission failures, mission successes, and response times to threats. This information will be made available to convoy rehearsal training managers and supervisors through a LMS.

Intelligent Tutoring

Intelligent tutoring technology allows for immediate feedback to trainees as they engage in interactive course material or rehearse a mission. A common method is to use animated agents that interact with the trainee by providing instruction and feedback as needed. Another option is to withhold immediate feedback in favor of a comprehensive automated after action review. Either way, the intelligent tutor provides several advantages compared to live instructors. The intelligent tutor can be available 24 hours a day, 7 days a week, with minimal per-user costs. It can also provide scalability of the simulation down to a single participant without sacrificing a positive training experience. Another advantage is that while human instructors can only observe one thing at a time, intelligent tutors can have visibility over every element of every situation for every user and can provide comprehensive, objective, and unique feedback for each user. These systems require tight integration with the training product but are shown to produce significant improvements in student performance. Measurable cost savings are also realized by moving coursework, as appropriate, from the classroom to the network. Intelligent tutoring currently requires further research and development in the area of team and leadership performance assessment before it can be considered a fully mature technology (RDECOM, 2004). However, even basic intelligent tutoring technology provides a critical capability for the Air Force trainer by providing for scalability down to the single user level.

Collaborative

The value, functionality and importance of team-based training are well documented (Brannick, Salas & Prince, 1997). Many of the game-based training products are being deployed via laptop computers for team training. Ambush!, for instance, is a game-based training application deployed by the US Army for convoy operations. It is specifically designed as a "table top" trainer where laptops are networked for interactive team based training. Close interactive immersive training such as this is effective at producing team cohesiveness and functionality, and is important for the Air Force convoy trainer. Key to a collaborative environment is the capability to participate with other users distributed around the world via the NIPRNET. Many user communities, including Air Force Transportation Specialists, are too small to dedicate a large percentage of their workforce simultaneously to a training event. The ability for multiple geographically separated units to each contribute just a few users at a time enables full-team simulations with minimal impact on day-to-day mission accomplishment. Distributing the simulation across the NIPRNET allows teams to train together prior to deploying and Air Force convoy tractor-trailer drivers to work with the Army gun-truck teams who will be supporting them in theater before they deploy. This ability to practice missions together can strengthen teams for the real-world combat environment.

Audio Communication and Sound

Relevant and accurate representation of audio cues as well as audio communications between collaborative team members can be an important component in rehearsal training. Digital voice communications have long been a part of large-scale military training exercises and are well understood in the DoD modeling and simulation community. The Navy Battle Force Tactical Trainer (BFTT) system sends and receives Distributed Interactive Simulation (DIS) packets using audio compression techniques and modern voice communication protocols requires only a single digit percentage of the overall network bandwidth (S. Giambarberee, NAWCTSD, personal communication, May 28, 2008).

Audio middleware software, such as the Unreal Engine 3® audio system from Epic Games, is well-established in the game development community. This software connects developers with the hardware so they can link sounds to objects in the game so that they are correctly represented according to the user's situation in the scenario (Brandon, 2007). For instance, a Warfighter in a tactical vehicle should not be able to hear the conversation of another Warfighter talking in a truck cab (without using a radio).

Authoring

Operation Iraqi Freedom has brought to the forefront the need to be able to respond to new and evolving threats. As insurgents asymmetrically adapt their warfare, the ability of US forces to maintain the upper hand in the conflict depends on their ability to develop new counter tactics (Grossman, 2004). Training systems play a key role in maintaining readiness, so they too must be able to evolve. Training systems that allow *authoring*, the ability to easily change the learning scenario and environment, best serve this purpose (Carr, 2008). While many warfighter subject matter experts (SMEs) undoubtedly have the skill and ability to modify software in training devices (especially the ones that are game-based), their job is to prepare for and fight battles. The challenge to designing any authoring system is to strike a balance between ease of use and the SME (usually an instructor) being able to portray realistic operational situations for the benefit of the trainee.

Interoperability

DoD simulation environments have historically been paired with interoperability specifications and standards for trading entity state data to form one large homogeneous wargaming system. The Air Force convoy rehearsal requirements include interoperability with Distributed Interactive Simulation (DIS), Test and Training Enabling Architecture (TENA) and High Level Architecture (HLA) with the latter being the most prevalent. The commercial gaming community has not embraced DoD interoperability specifications and standards, but there have been some attempted implementations mixing these technologies (Spaulding, Morissette & Morales, 2005).

SOLUTION APPROACHES

Web Browser Delivery

As discussed, the typical commercial game and military simulation approach of employing special-purpose computing hardware is not practical for the generic DoD computing environment. Seat management approaches and the DoD IA climate both impose significant restrictions. Web browsers, however, are already installed on all NIPRNET computers. Compared to accrediting hundreds of different applications or purchasing and sustaining dedicated computers and networks, a web delivered approach is a highly cost effective way to deliver training worldwide. For these reasons, web browser delivered technologies were investigated as potential solution approaches for the aforementioned trainer requirements. Video streaming, browser plug-ins and the Windows platform are three technologies that hold promise for enabling the web browser to deliver a robust simulation experience across the network enterprise.

Video Streaming

Several companies are working to deliver 3-D content by rendering it on a server and streaming it over the Web. This can be done with either a "one-to-many" or a "one-to-one" approach. The one-to-many approach, where each user sees the same image on his desktop as seen by the other users, is useful for live, distributed classroom instruction. First person simulations require the one-to-one approach since each user must be able to participate in the world from their own perspective. Operating system virtualization allows multiple users to share servers while using systems that do minimal processing at their desks.

Streaming presents possible limitations for the highly interactive graphical applications involved. Bandwidth requirements are more likely to exceed infrastructure capabilities since even highly compressed video involves more data than networked simulations require for communicating contextual entity state data. Finally, latency mitigation for streaming is not compatible with the existing infrastructure since it relies on reducing the distance between servers and clients by geographically distributing the servers. Edge servers can do this for static content, but are still being investigated for dynamic content. The clients involved may still constitute software that requires installation by an administrator, as well as server-side accreditation for both the streaming software and the simulation software running on the server.

Browser Plug-ins

Several browser plug-ins are already accredited and included on all Services' standard software configuration builds. Adobe® Flash® and Microsoft Silverlight™ 1.0 enable low-bandwidth rich 2-D graphics and video streaming. Microsoft Silverlight 2.0 and Adobe Shockwave® enable fairly robust 3-D graphics, and some versions of Shockwave include physics engines. There are some implementations of first-person games written in Shockwave that demonstrate some impressive and applicable capabilities, however inconsistent access to Shockwave across the DoD restricts the viability of its application to this problem.

Windows-based Technologies

Sun Microsystems® Java® and Microsoft® ActiveX® software technologies, and the Microsoft Windows Presentation Foundation (WPF) development platform revolutionized the internet browser's ability to deliver rich 3-D simulation content. Java and ActiveX are standard in DoD end user computer systems. WPF has been in Microsoft .NET Framework since version 3.0 and is also included in each military Service's standard computer software configuration build.

In order to fully discuss Windows components, we must consider the two ways code can be developed for the Windows environment. Prior to the .NET Framework, all Windows-based code was "unmanaged", or "native"; that is, once the code is compiled, it runs directly on the machine. "Managed" code, on the other hand, compiles to an intermediate language that runs in the .NET Common Language Runtime (CLR) which provides memory management and security at runtime (Gregory, 2003). The big advantage is that managed code allows more options to deploy robust web applications. The disadvantage is that the CLR constitutes an additional layer that can interfere with the optimizations required for time and resource sensitive applications such as real-time 3-D graphics rendering. This establishes an inherent disadvantage for 3-D engines written in managed code and explains why WPF browser-based 3-D engines have not proliferated. Maximum performance still drives the industry more than ease of deployment in restricted environments.

InstantAction is an existing Commercial Off The Shelf (COTS) ActiveX browser plug-in from game developer GarageGames (Emeran, 2008). It comes standard with the Torque engine, but pledges to enable any C++ game engine to run in a browser window (Cork, 2007). It is not difficult to "wrap" any existing C++ application into an ActiveX control to be executed through the browser, and many firms have extensive experience in this field. ActiveX works with both native and managed code, but unfortunately requires installation by a network administrator because doing so modifies the Windows Registry and the "Program Files" folder.

WPF can work and has the capability to deploy completely over the web with something called an Extensible Application Markup Language (XAML) Browser Application (XBAP) file. XBAP can be thought of as a Microsoft .NET version of a Java applet. Like ActiveX controls, WPF XBAPs can call native code already installed on the machine. If written exclusively in managed code, it can also reside entirely in a WPF browser application. This offers the possibility to provide limited 3-D capabilities without the need for any assistance from an administrator. Unfortunately, current security controls prevent the XBAP from persisting on a per-machine basis and being accessible to all users without each having to do their own initial download. The only alternative is installation by a system administrator, the same drawback as the ActiveX approach. Per-user data persistence also wastes hard drive space, download time and bandwidth on shared computers and for all but the smallest applications.

There are currently no robust XBAP 3-D engines on the market. The anticipated cost of developing a XBAP 3-D engine makes wrapping existing native code in ActiveX controls far more affordable than developing a pure managed WPF approach. Similarly, no Java 3-D engines robust enough to meet the requirements are known. Thus, the combination of native binaries and ActiveX controls becomes the most cost effective and lowest risk approach to delivering the required browser functionality.

Although native code ActiveX and WPF approaches cannot eliminate the need for local administrative support, they do allow execution in the browser, fit its client model, and thus appear to be the only options meeting all requirements to provide an enterprise solution. In essence, this approach provides a browser plug-in, custom built for the military to produce and execute mission rehearsals over the web.

Architecture

Regardless of which technical solution is used to deliver the simulation, the software must be built with an architecture optimized to deliver the capability. Two game genres rely on architectures similar to the needs of military simulations, but each diverges from military requirements for its own reasons. The ultimate solution will likely combine the best attributes of each.

First-person Shooter (or Thinker)

First-person shooter (FPS) game technology puts the trainees in the position of seeing the world through the eyes of their gaming avatars. The world is usually fully developed 3-D giving depth and substance to the simulation experience, and allowing for direct manipulation of objects. It is the key interface for many successful video games as well as many successful trainers such as Ambush!, the US Army's convoy trainer.

Ambush! offers many of the desired functions for the Air Force convoy rehearsal, but it also has some challenges. Three areas are of key concern: the data sets, graphic requirements and executable files required to run these types of games and simulations. Many modern games easily exceed a gigabyte (GB) of data. The networking interface requirements for Air Force convoy rehearsal make downloading this much data prohibitive in time and network consumption. Many modern gaming projects also require newer graphics cards not available under Air Force common computing environments to execute properly. Finally, the gaming executable would require C&A before deployment on DoD networks and computers.

Virtual Worlds

Virtual World (VW) technology is similar to the FPS technology, but there are some key differentiators. VW technology offers the ability to host many more trainees than gaming platforms. Where FPS gaming technology can generally host team training for numbers well under a hundred, VWs can host tens of thousands of persons per environment. Larger training events or gatherings are their forte. They also offer persistence. While a computer game generally starts at the same start point each time it is played, VWs can persist 24/7/365 and "remember" where the player was "at" when they left the world. Actions performed are remembered and affect the world indefinitely. This creates the potential for "case studies" in training worlds that can be passed from one training generation to the next.

Many commercial VWs exist primarily to provide users with both tools to create content (advertisements, buildings, vehicles, avatar "clothing" and accessories) and to showcase the content. This drives some VWs to download world data on a just-in-time or on-demand basis since it changes too frequently to allow caching. Additionally, many users will never return to most areas they visit, so there is little point in caching the content anyway. Downloading this much data at execution requires low latency and high bandwidth pipelines to deliver a productive user experience. The required computer interfaces consists of hundreds of megabytes to several GBs of data installed on the client. These executable files, as in the gaming case, must be security-verified before deployment on DoD computing assets.

The ideal architecture solution for conveying distributed military simulations over common networks will likely include elements of both FPS and VW technologies. Such a solution might combine VW technology's ability to support large numbers of users and ease of authoring with FPS technology's approach of preloading graphical data. Also, visual fidelity will need to be scaled to the lowest common denominator of hardware capability.

CONCLUSIONS AND RECOMMENDATIONS

Use of commercial game engines to power military simulations has fueled a transformation in military training systems, but so far the benefits have only reached small communities. The military will need to overcome delivery challenges in order to make it available to all who need it. Leveraging existing computer and network infrastructure using a web client to deliver the capability to the user mitigates or solves each of the problems.

The hardware problem is mitigated by a combination of accepting a level of visual fidelity attainable with mature graphics technology and by pushing heavy processing requirements to a server. These approaches enable even four-year-old computers to perform first person simulations adequate for doctrine and TTP reinforcement.

To mitigate the problems presented by the need to install software, the military can commission production of an accredited, highly reusable, DoD enterprise licensed custom browser plug-in to produce and execute mission rehearsals in concert with server support. Accrediting the browser client does not represent significant additional overhead since server software would require accreditation anyway—they get accredited together. Once this single application is accredited by each of the services, it may be installed on all DoD computers, providing functional organizations and training communities the ability to outsource or produce their own training content for any skill enhanced by first-person simulation. They can then distribute the training worldwide at no cost to their users. After fielding the system, the only direct costs are keeping the servers running and purchasing additional servers to host new training content or to expand concurrent user capacity. Generally, servers tend to scale to 100 users each. When enough training content is offered for use on this framework, the Services can justify including the plug-in on their general office computer standard disk images thus solving the software installation problem.

The recommendation is for the military to acquire and field the web-client based mission rehearsal capability discussed in this paper. This is the next logical step toward implementing game-based military training systems on a large scale. The Air Force is implementing their combat convoy mission rehearsal training requirements through the Tactical Mobility Mission Planning (TM-MP) program. The result will be a browser-based game-based training application with 3D graphics capability using ActiveX.

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