instructions with host safety checks or scans. It will also prototype the scalable infrastructure needed to mint, confirm, and manage secure attention instructions.

Because we have limited resources, we chose to implement our prototype as a PCI-bus peripheral protecting the open-source Linux kernel. Intelligent peripherals have the necessary local processing power and interface restriction capabilities to be relatively omniscient (as bus masters) but tamper-resistant. An Intel IQ80310 prototyping board provides these features and saves hardware prototyping effort.

[Sponsored by ONR]

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Virtual Targets for the Real World

D.G. Brown,[1] Y. Baillot,[2] K.C. Pfluger,[3] S. Julier,[2] and M.A. Livingston[1]

[1] *Information Technology Division*

[2] *ITT Advanced Engineering and Sciences*

[3] *Reallaer LLC*

Introduction: Live-fire training keeps warfighting capabilities at peak effectiveness. However, the cost of procuring real targets—only to be destroyed—is prohibitively expensive. The United States Marine Corps (USMC) uses a variety of target proxies, such as derelict vehicles, piles of waste, and even "pop-up targets," all of which are nonreactive, stay in fixed locations from year-to-year, and often do not resemble the real targets. Trainees simply do not get the opportunity to fire live rounds at realistic-looking and moving targets. However, Augmented Reality (AR) can help by merging virtual entities with the real world for training exercises. We describe an AR system that provides virtual targets for training of USMC Fire Support Teams.

Augmented Reality: In an AR system, the user wears a tracked see-through head-mounted display with stereo headphones that is connected to a computer containing a database of spatial information related to the venue of the training exercise. By measuring the user's position and view direction in the real world, three-dimensional (3D) computer graphics and spatially located sounds are displayed to appear to exist in the real world. A miniaturized and ruggedized computer, batteries, and wireless networking make the AR system man-portable. Figure 3 shows a mobile AR prototype system. In the case of AR for training, the virtual information overlay consists of realistic 3D renderings of entities: individual combatants, tanks, planes, ships, etc.

Entities in Training: Entities in training exercises fall into one of three categories: *live* entities are real people and vehicles participating in a training exercise; *virtual* entities are human-controlled players in virtual worlds; *constructive* entities are driven by algorithms in computer simulations. AR provides a natural way for all three types to mix together. Live entities observe virtual and constructive entities through the AR system. Interactions such as shooting are conveyed from the AR system back to the constructive and virtual simulation systems.

Application of AR for Fire Support Team Training: The USMC's Fire Support Team training begins with small-scale (1:40) pneumatic mortars on a field at the Marine Corps Base, Quantico, Virginia. The purpose of this training is to hone the communication skills between the forward observer and the Fire Direction Center (FDC). In the current training plan, a forward observer visually locates targets, identifies and determines grid coordinates using binoculars and a map, and recommends a call for fire to the FDC. Once the shots are fired, the training instructor (not a part of the operational fire support team) determines the accuracy of the shots and the effect on the target: catastrophic hit, mobility hit, or no effect. The calls for fire are adjusted until the team has the desired effect on the target. Before introducing the AR system, the team fired on static and unrealistic proxy targets.

The system, based on the Battlefield Augmented Reality System,[1] was demonstrated at Quantico in October 2004. It provides a head-mounted display for the forward observer and a touch screen for the instructor, each showing virtual targets on the real range. Figure 4 shows the observer's view of virtual targets and buildings on the range. The observer can have the computer simulate a magnified view (including a reticle), similar to the view binoculars provide, to determine target identity and grid coordinates. The targets move along preset routes and are started and stopped by the instructor through a simple interface. As before, the forward observer calls for fire on the targets and a real round is fired. The instructor sees where the round lands in the augmented touch screen view and designates the effect on the target. Through a dynamic shared database,[2] the forward observer sees that effect and revises the call for fire. Figure 5 illus-

FIGURE 3
Mobile Augmented Reality (AR) prototype system.

FIGURE 4
Observer's view of virtual targets and buildings on the range.

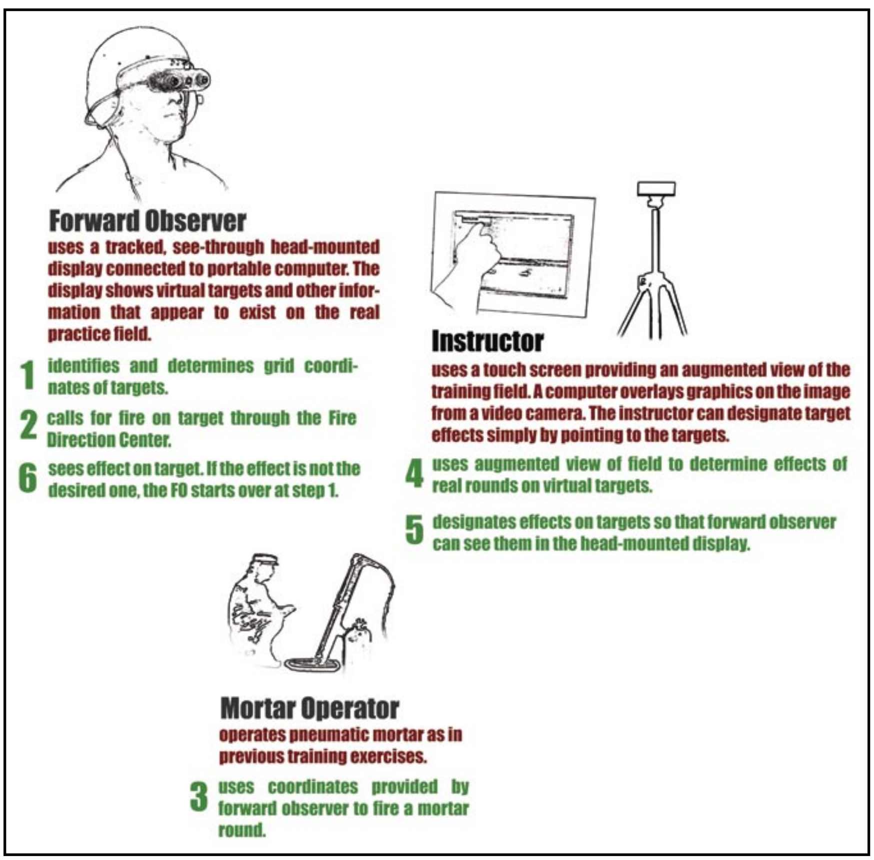

FIGURE 5
Augmented Reality (AR) system's major components and steps in the system's usage.

trates the major components of the system and steps in the system's usage. Augmented Reality was inserted into the training plan with no significant changes to the duties and actions of the participants, except that they can now fire on moving targets.

The virtual targets for training were well received by the mortar trainees and instructors at Quantico; however, rigorous studies and measurements of effectiveness are yet to be done. The system can also insert virtual terrain and control measures into the display, and both capabilities were preliminarily tested at Quantico. Future plans include refining the system, taking it to a full-scale live fire range such as the Marine Corps Air Ground Combat Center, Twentynine Palms, California, and completing a Semi-Automated Forces (SAF) interface for more intelligent targets.

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Course of Action Analysis in the Global Information Grid

R. Mittu
Information Technology Division
J. Walters
ITT Advanced Engineering and Sciences

Introduction: The Department of Defense (DoD) is investing resources to support the development of the Global Information Grid (GIG)[1] a services-oriented architecture (SOA) based on web services technology (Fig. 6). The GIG will enable interoperability between all levels of military systems, sensors, simulations, operational users, autonomous software agents, etc., in tasks that range from purely administrative through complex Command and Control functions throughout the DoD. This article discusses the participation of NRL in a GIG proof-of-principle prototype that uses web services to provide the connectivity between the Global Command and Control System (GCCS),[2] Joint Warfare Simulation (JWARS),[3] as well as intelligent software agents to support Course of Action Analysis (CoAA). We also describe two of the many challenges that software agents must overcome to realize the full potential of the GIG.

Web Services and the GIG: The World Wide Web Consortium (W3C)[4] is leading the development of web technology, including web services technology such as the Universal Description Discovery Interface (UDDI), Web Service Description Language (WSDL), and Simple Object Access Protocol (SOAP). The UDDI defines web registries to which businesses can upload information about themselves and the services they offer. A WSDL document describes the locations of services and the operations supported by that service. The SOAP is a simple markup language for describing messages between applications. It is used to interact with UDDI registries to locate WSDL documents and to interact with the corresponding service described within the WSDL.

The GIG infrastructure will provide an open environment in which all military systems and users can seamlessly share information, without restrictions and limitations imposed by the current operational DoD architecture, which provides stovepiped interconnectivity between components (e.g., interface points between systems or components are inflexible and nonrobust to change or adaptation). The GIG represents a transformational shift, from stovepiped to a more flexible architecture, providing the opportunity for systems and users to dynamically discover and interact with other systems/users via web services. Figure 6 shows the GIG layers.

GIG Proof-of-Principle Prototype: Simulations are increasingly being used during operations to perform CoAA and develop real-time forecasts of future battlefield conditions. The Defense Modeling and Simulation Office (DMSO) is sponsoring a prototype to demonstrate (1) the utility of web services for providing interconnectivity between GCCS, JWARS, and intelligent agents; (2) the value added in using a standard data model to enable semantic interoperability between each component; and (3) the role of intelligent agents to support meaningful CoAA. NRL is responsible for developing the intelligent software agents; the Naval Warfare Development Command (NWDC) is responsible for web-service interfaces for GCCS and CACI Federal for the overall integration effort as well as the web service enhancements to JWARS.

GCCS is an automated information system designed to support situational awareness and deliber-