Extending the 'Serious Game' Boundary: Virtual Instructors in Mobile Mixed Reality Learning Games

Jayfus Doswell
The Juxtopia Group, Inc.
3403 Lynchester Rd.,
Baltimore, MD 21215, USA
doswellj@hotmail.com

Kathleen Harmeyer
University of Baltimore Simulation & Digital Entertainment
Yale Gordon College of Liberal Arts
University of Baltimore, 1420 N. Charles Street
Baltimore, MD 21201, USA
kharmeyer@ubalt.edu

ABSTRACT
Virtual Instructor enabled mobile augmented reality learning (MARL) games have the potential to provide a fun and educational experience. In these types of "serious games", learners/game players may wear a mobile heads-up display that provide a rich graphical interface over the real world allowing the real world to be augmented with digital annotations including animation, graphics, text, and video. Graphical annotations may highlight specific real-world objects that hint the player to manipulate an object in order to achieve a certain objective in the game. Additionally, a mobile headset may display resource stats including, but not limited to, team hit points and geographical location of individual team members participating in the game experience. Furthermore, a virtual instructor may assist in providing instruction on how to play the video game and assist students in solving challenges that require academic skills. Hence, in a MARL game, a virtual instructor may provide continuous and autonomous instruction or guidance to the game player/learners anytime, anyplace, and at any-pace. The virtual instructor may serve as a mission leader or guide for the player's real-world quest.

Author Keywords: video game, serious games, mobile, augmented reality, virtual instructor, software architecture.

INTRODUCTION
Mobile Augmented Reality Learning (MARL) games that incorporate virtual instructors and provide on-demand and location based instruction have the potential to augment learning anytime, anywhere, and at anypace in fun and exciting ways.

A virtual instructor that provides a personalized human learning experience by applying empirically evaluated and tested instructional techniques can be distributed in novel "serious games" and have the potential to continually improve human learning performance [2][3]. Instructional techniques, combining the art and science of teaching (i.e., pedagogy), may be exemplified by three dimensional (3D) animated characters as virtual instructors that intelligently consider multiple variables for improving and potentially augmenting human learning. These variables include, but are not limited to learning styles, human emotion, culture, gender, and pedagogical techniques. The virtual instructor can be displayed as an animated 3D character displayed through a wearable heads-up display device. However, in order to serve as an effective 'edutainment' experience, the virtual instructor enabled MARL must combine the knowledge of "master" instructors that possess expertise in specific academic/knowledge domains, understand how humans learn, and effectively deliver instruction based on its location or environmental context (e.g., outdoors, museum, classroom, etc.). These are computational challenges for the virtual instructor and MARL developers. A interdisciplinary research team with expertise in areas such as cognitive science, sociology, computer software engineering, computational humanities, educational technology, artificial intelligence, 3D computer graphics, linguistics, and display technologies is required. An effective approach for developing a virtual instructor enabled MARL game is the focus of this paper.

BACKGROUD
Mixed Reality
Augmented reality (AR) falls within Milgram's mixed reality continuum. In *augmented reality*, digital objects are added to the real environment. In *augmented virtuality,* real objects are added to virtual ones. In *virtual environments* (or virtual reality), the surrounding environment is virtual.

Situated Play, Proceedings of DiGRA 2007 Conference

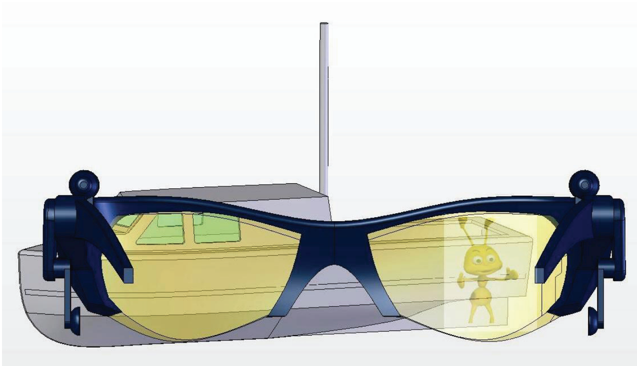

Figure 1: First person view of MARL Game Goggles viewing boat in outdoor learning environment with an embedded virtual instructor.

As illustrated in Figure 1, one form of AR is facilitated with a see-through head mounted display worn over a user's eyes (like goggles) that overlay the human visual field with animation, computer graphics, text, or video. AR systems integrate virtual information into users' physical environment so that they will perceive information as existing in their surroundings. AR is related to the concept of virtual reality (VR), but contrast VR. In VR, a user is immersed in the world of the computer. VR attempts to create an artificial world that people can experience and explore interactively, predominately through their sense of vision, but also via audio, tactile, and other forms of perceptual feedback. AR also brings about an interactive experience, but aims to supplement the real world, rather than create an entirely artificial environment. In AR, the physical objects in the individual's surroundings become the backdrop and target items (e.g., historical buildings), for computer-generated annotations (e.g., names of the buildings). Thus, AR systems combine, and in real-time, align virtual objects with physical ones.

Virtual Instructors In Mixed Reality

The advantage of designing virtual instructors to operate in AR environments is their ability to intelligently deliver instruction/guidance based on the learner's context such as geographical location (e.g., historical park) and current knowledge of a particular subject. Additionally, virtual instructors may use the best instructional method for motivating the player/learner, reinforcing learning concepts, and providing guidance through new and complex tasks. For example, if the mixed reality game is about a historical quest, then virtual instructors may be loaded in the game and serve as an historical sage, providing historical facts and initiating animated sequences of historical references based on the player's position in the real-world.

AR presents a particularly powerful human computer interface (HCI) to context-aware computing environments and for the distribution of virtual instructors through the use of mobile or wirelessly enabled AR systems, Mobile Augmented Reality Systems (MARS).

Mobile Augmented Reality System (MARS) Games

MARS combines research in AR and mobile/pervasive computing, in which increasingly small and inexpensive computing devices linked by wireless networks, allow learners to roam freely between indoor and outdoor environment and collaborate with other MARS users [6]. MARS provides a location independent service without constraining the individual's whereabouts to a specific geographical location. By doing so, this technology holds the potential to revolutionize the way mobile games are played and information presented. MARS applied to learning games is considered a Mobile Augmented Reality Learning (MARL) game and has the potential to provide on-demand and context-aware instruction to K-12 aged students as well workers in various industries, including, but not limited to medical, military, and manufacturing industries. The MARL game concept is derived from empirical research in Augmented Reality games [5][12][13][14][15].

One rich interactive learning experience in a MARL game is the virtual instructor. The building blocks of the 3D computer animated virtual instructor are virtual humans that have started to penetrate our daily operations, starting by inhabiting our auditory world [10]. For example, if people call British Airways, they can have a satisfactory conversation with their virtual reservation agent. Through a combination of state of the art vocabulary, over the phone speech recognition, and natural language processing, one can talk with a pleasantly mannered virtual human about anything within the domain of a British Airway reservation. On the web, virtual talking heads are starting to emerge with definitive personalities incorporating face animation, and avatars representing virtual reality participants. The international noted author and "futurist", Ray Kurzweil stated that by year 2010, virtual humans will have the ability to pass the Turning Test. In his prediction, people will not mistake virtual humans for real ones, but will interact naturally with them as information assistants, virtual coaches, virtual sales clerks, entertainers, and even for love replacement therapy [10]. Perhaps, one of the most important applications of virtual human technology will be in the teaching domain. Because virtual instructors may be realistically designed to operate separately from school system politics and policies, it would be difficult to attribute alternative motives to an animated character. Additionally, a virtual instructor will work just as efficiently with no pay and teach with its main goal to improve the knowledge of the human learner with options to teach to the traditional curriculum or extend it. Furthermore, traditional education is going through an evolutionary stage [10] and more people are realizing that specialized knowledge acquisition rather than traditional grade level elevation contributes greatly to human "success".

With an innovative model of virtual instructor lead augmented reality learning, humans may be effectively taught at their own pace and receive personalized instruction services [1][7][9][11]. However, very little research has demonstrated an approach for a virtual instructor lead AR learning experience. Additionally, very little research has exemplified context aware learning through a MARL game.

MARL GAME SERVICE PLATFORM

To build a virtual instructor enabled MARL game platform requires an extensible, interoperable, modular, and scalable software architecture model. Comprehensive research has been conducted to design such an architecture model, the Context Aware-Augmented Reality System (CAARS). The CAARS architecture was initially developed for the Manufacturing Training domain but has been extended for developing MARL game environments.

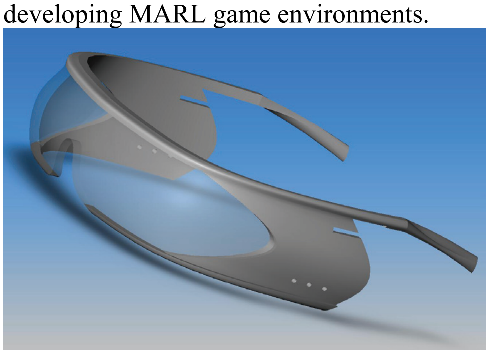

Figure 2. CAARS "See-Through" Goggles

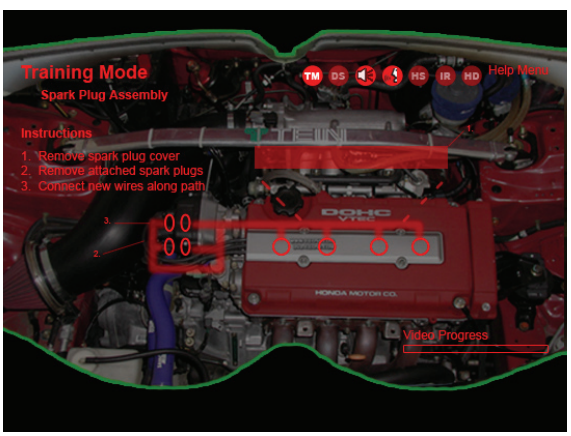

Figure 3. CAARS Goggle User's View of Auto-Engine

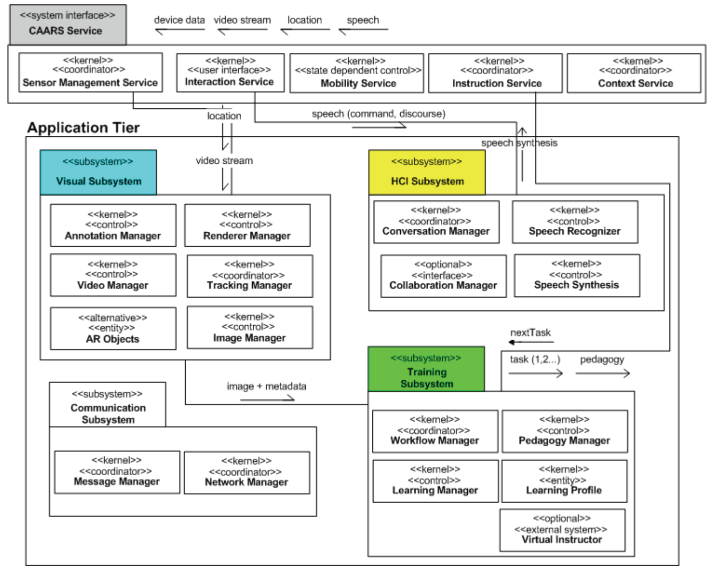

Figure 4. CAARS High Level Architecture

CAARS goggle design: The CAARS goggles are illustrated in Figures 1 and 2 and were designed as a ruggedized, light-weight headset designed for comfort and safety and with several major components including, *optical see-through display*, *antenna*, *speaker*, and *lithium ion rechargeable batteries*. Figure 3 illustrates a user's view, while wearing AR 'goggles', of a car engine where digital annotations are superimposed to identify engine parts and provide instructions to the user.

Considering the fact that current *optical see-through displays* are bulky and have awkward structures that minimize its commercial potential, the researchers designed a novel optical see through AR heads mounted display that is light-weight, comfortable, and aesthetically pleasing. Research investigators chose optical see through displays as opposed to video see-through display because optical see through displays preserves the real image while reducing degradation.

Additionally, the CAARS goggles were designed with a miniature PC compatible camera to capture visual elements in a learner's environment (e.g., historical trails, architectural artifacts, etc.). As images are captured by the camera, they may be transmitted, wirelessly along with meta-data, in real-time, to the *MARL Game Service Platform* for processing by *software agents* for on-demand delivery of training assistance or game play guidance.

A wireless antenna was integrated to function as a transceiver in order to transmit and receive digital information from and to the CAARS AR goggles. This allows the CAARS goggles to remotely transmit real-world images, position coordinates, head orientation coordinates, and sound from mini-cameras, inertia sensors, and mini-microphone input-sensors. Speaker were also integrated into the CAARS goggles to facilitate hands free commands of instructional material as well as to sound broadcast alerts and other information relevant to a training session. The CAARS goggles were also designed to be powered with rechargeable lithium ion batteries for operation up to 8 hours.

As a result of the CAARS goggle design, learners may request various tasks assistance through simple voice commands and, as a result, visually see and hear assistance through the optical see through display and mini-speakers, respectively.

CAARS Service Oriented (SOA) Architecture:
The MARL game service may be delivered by a service oriented architecture (SOA) made up of several subsystems that provide visual, human computer interface, and training services. The services are high level software interfaces that encapsulate the lower level objects allowing for improved software algorithms to be continually implemented and incorporated into the system. The visual subsystem handles the image recognition and analysis to facilitate accurate real-world object recognition (e.g., recognize historical landmark). The human computer interface (HCI) subsystem controls the speech recognition and speech synthesis services that enable hands free and a more natural interactive MARL game. The training subsystem uses a combination of software agents and pedagogical models to guide learners understand concepts and perform step-by-step procedures for completing tasks (e.g., techniques for assembling a robot for the game play). To facilitate this functionality, the training subsystem contains software agents that intelligently control the administration of training scenarios. Various pedagogical techniques such as "scaffolding" were investigated and learning profiles accessed by intelligent software agents to deliver personalized training. Using this technique, the training subsystem may identify novices and provide them more step-by-step instruction than those with higher level experience in a particular subject domain. Additionally, a search engine component was incorporated to facilitate context-based and voice-driven information retrieval. It uses meta-data to expedite the search for instructions and corresponding 2D/3D graphic and video/animation sequences to assist the learner through tasks completion.

The Training subsystem interfaces with the Pedagogical Embodied Conversational Agent (PECA) system software architecture [2]. The PECA Product Line Architecture is designed to generate families of virtual instructors that may provide instruction from mixed reality environments such as virtual reality, augmented reality, volumetric displays, holographic environments, and adapt to evolving virtual environment technologies. The PECA Product Line Architecture was developed to address limitations in dynamic 3D animation, knowledge domain dependence, autonomous operation within mixed reality environments, realistic interaction with human end-users, and pedagogical intelligence. The PECA Product Line supports the "plug-in-play" integration of various system/software components [4] ranging from speech recognition and speech synthesis components to 3D animation algorithms and pedagogical techniques. Software components were built using a combination of Java and C++.

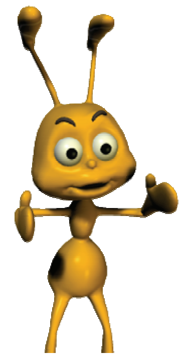

Figure 5: 3D Animated Virtual Instructor Ant

Figure 6: 3D Animated Virtual Instructor Heroes

Virtual instructors for use in MARL games (as illustrated in Figures 5 and 6) were generated from the PECA Product Line architecture and respond to multimodal external inputs. Multimodal inputs supported in all PECA Product Line virtual instructor systems include human body gestures (i.e., face and body) and human environment (e.g., toys) captured by digital camera devices; and human verbal input and human environment noise captured by microphone devices. Optionally, a virtual instructor system created from the product line may support the capture and interpretation of human physiological data captured from biosensors to add additional context and provide more information about one's learning progress.

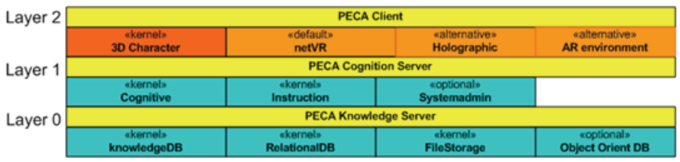

Figure 7: PECA Layered Architecture View

Figure 7 illustrates the multi-tier view of the PECA Product Line Architecture. This view is based on the *Layers of Abstraction* pattern (also known as the Hierarchical Layers) [4]. In this view, the PECA Knowledge Server, PECA Cognition Server, and PECA client tiers are depicted as Layer 0, Layer 1, Layer 2, respectively. Subsystems and corresponding components each reside in these individual layers. In the PECA Client tier, the 3D Character (i.e., virtual instructor) is the kernel graphical component with which the end user (i.e., learner) interacts. The netVR, Holographic, and AR environment are alternative mixed reality environments in which a virtual instructor may be integrated. Because these environments are denoted as alternate, one and only one mixed reality environment must be selected in which virtual instructor will inhabit. The PECA Cognition Server is the most dynamic aspect of the three layers with regards to system configuration and component/subsystem updates. The PECA Knowledge Server has several data repositories with which the PECA Cognition Server interfaces. Data repositories including knowledge databases/expert systems, relational database systems, and file storage systems are kernel data repositories supported by the PECA Product Line Optional data repositories may be XML, object oriented databases, among other data repositories.

CONCLUSION AND FUTURE DIRECTION

Figure 8: MARL game mixed reality prototype

A virtual instructor enabled MARL game may serve as a fun and natural learning interface to assist learning conceptual knowledge as well as psychomotor task in real-world environments. Applications created from the MARL game approach have implication in K-12 education, graduate and post graduate learning.

Continued research is planned to conduct empirical research studies using virtual instructor enabled MARL games to assist learners of all ages accelerate their learning, receive individualized instruction, and moreover, make learning extremely fun. Additionally, researchers working on this project plan to combine their research on MARL games with a Massively Multi-player Online Role Playing Game (MMORPG) prototype (illustrated in Figure 8) to consistently provide the same set of virtual instructors in both augmented reality and virtual reality environments.

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