Using Augmented Reality to Tutor Military Tasks in the Wild

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ABSTRACT

Intelligent Tutoring Systems (ITSs) have been shown to be effective in training a variety of military tasks. However, these systems are often limited to laboratory settings on standard PCs and laptops which focus on exercising cognitive skills (e.g., decision-making and problem solving) and may potentially limit the learning and retention of the dismounted Soldiers and Marines training to master physical tasks. Augmented reality presents the possibility of combining intelligent tutoring with hands-on applications in realistic physical environments. In this paper, we examine the use of an augment-reality based adaptive tutoring system for instruction in the wild, locations where no formal training infrastructure is present, and identify the challenges that arise when developing such a system. We began the transition from desktop tutoring to the wild by exploring an existing real life mockup of a market scene along with low cost commercial-off-the-shelf devices (e.g., HMDs coupled with depth cameras) and a 3D model of the environment. The goal of our canning approach is to use "human in the loop" 3D scene acquisition via augmented reality so that the scene can be scanned efficiently and with complete coverage. Using this 3D model, intelligent tutoring systems can adaptively manage instruction while being aware of the physical and augmented objects in the scenario. Furthermore, with this awareness of the physical environment, we hope to provide augmented effects and objects (e.g., virtual humans) that register to the physical environment and respond realistically to interactions with the trainee. We also explored developing a training scenario for evaluation of our system that is made to work with emerging low-cost commercial augmented reality devices (e.g., Epson Moverio). Our approach examines the merging of intelligent tutoring with augmented reality to be used for hands-on immersive training of psychomotor tasks in a setting beyond the typical desktop tutoring session.

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Dr. Robert A. Sottilare leads adaptive training research within the US Army Research Laboratory where the focus of his research is automated authoring, automated instructional management, and evaluation tools and methods for intelligent tutoring systems. His work is widely published and includes articles in the Cognitive Technology Journal, the Educational Technology Journal, and the Journal for Defense Modeling & Simulation. Dr. Sottilare is a co-creator of the Generalized Intelligent Framework for Tutoring (GIFT), an open-source tutoring architecture, and he is the chief editor for the Design Recommendations for Intelligent Tutoring Systems book series. He is a visiting scientist and lecturer at the United States Military Academy and a graduate faculty scholar at the University of Central Florida. Dr. Sottilare received his doctorate in Modeling & Simulation from the University of Central Florida with a focus in intelligent systems. In 2012, he was honored as the inaugural recipient of the U.S. Army Research Development & Engineering Command's Modeling & Simulation Lifetime Achievement Award.

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INTRODUCTION

Intelligent Tutoring Systems (ITSs) have been shown to be an effective means to train soldiers in cognitive task domains (Jensen, Sanders, Mosley, & Sims, 2009; Sottilare & Gilbert, 2011; Goldberg, Sottilare, Brawner, & Holden, 2012). Currently these systems are primarily desktop applications running with mouse and keyboard interaction in a classroom setting. While still effective for some training tasks, it is possible to expand upon this capability with an approach that uses augmented reality to create realistic scenarios for more effective training which more closely matches the physical aspects of soldier tasks. We call this “in the wild” intelligent tutoring, training in locations where no formal training infrastructure is present, and it shows great potential to support psychomotor task performance improvements. In addition, by superimposing virtual humans into the real world, we can create more interactive and immersive ITSs.

We initially explored Virtual Reality, also used for military training, but it did not provide sufficiently realistic human interaction support for the tasks we examined, lacked the ability to use real objects to support tutoring in the wild, and occluded the trainee’s field vision of the real-world. With augmented reality a realistic set was used as an initial proxy for a live environment (Figure 1), to create effective training scenarios where the bluescreen was used to represent virtual elements.

Figure 1. An example village residency we used to explore AR-based tutoring.

To use augmented reality, however, there are several challenges that must be overcome. For example, virtual humans must be registered or placed in the correct position and at the correct size, given their location from the user’s current position and orientation. These virtual humans and virtual objects must also be obscured correctly if standing behind an object, otherwise they will not appear realistic and the spatial relationship developed by the trainee observing the avatar may become skewed. Additionally, the virtual world must also be aware of the position and field of view of the trainee so the objects in the scene scale properly and react to the trainee as the trainee moves around them.

The issue of making the augmented reality environment aware of the real world can traditionally be a timely process as a virtual model must be created that accurately reflects the physical environment. By looking to the latest research and COTS devices, we are exploring an in-the-wild approach, which means any environment may be easily developed into a realistic augmented reality training scenario.

In this paper we discuss two systems being developed to accomplish this goal. One focuses on scanning in the environment before training scenarios are commenced and the other, dubbed ARWILD, combines these scanned models with augmented reality and intelligent tutoring systems.

With the scanning process we looked at available projects that provide source code we can modify for our needs. The goal was to create a human-in-the-loop scanning system with a depth camera mounted upon the augmented reality viewer which can provide the user with real time feedback of the model's generation progress. We discuss current progress to date, the limitations of current scanning software, and how the human in the loop is capable of improving the process.

In the second part of this project, we discuss ARWILD, our proof of concept intelligent tutoring system that utilizes the scanned 3D environment models and the Generalized Intelligent Framework for Tutoring (GIFT; Sottilare, Goldberg, Brawner, & Holden, 2012). We show a simple training scenario as an example with more complex scenarios being developed and tested in the future.

For this paper we make use of the Oculus Rift (Oculus VR LLC, 2015) combined with commercial webcams attached to the front to create an Augmented Reality viewing device. For depth scanning, we began with the Microsoft Kinect (Microsoft, 2015), but expanded this to a smaller easier to mount device known as the Structure Sensor (Occipital Inc, 2015). With this sensor we were able to create high definition 3D scans of our laboratory environment to be integrated into our simple training scenario.

We also made use of Unity 3D (Unity Technologies, 2015) to create the 3D training scenario. With this we were able to place models that were fully animated and capable of interacting with the user while also being integrated with a GIFT-based tutor for scenarios such as threat assessment, and ultimately mission rehearsal. With our current prototype, we developed a GIFT-based tutor for training proper protocol for interacting with a superior. The Metaio SDK (Metaio GmbH, 2015) was used to handle several of the issues with developing an augmented reality environment. This SDK was capable of taking the images observed by the cameras combined with accelerometers within our hand held computer to determine the location of the user and transform virtual humans within the augmented reality scene for realistic observation. This SDK is also capable of providing tools so that the virtual humans within the 3D scene may easily be placed within Unity relative to how they will appear in the augmented reality scene.

In the next section, we review work related to training soldiers in virtual and augmented environments along with work done on the development of these environments. Section three discusses how 3D scanning of the environment is performed and how it may be improved with future iterations. Section four looks at the ARWILD system and its integration with GIFT. Section five concludes our work with a discussion on how it is planned to evolve and how it may be used to gather significant statistics on its effectiveness.

RELATED WORK

The training of modern soldiers with virtual environments has been the focus of several research projects. Training may range from route learning and spatial training (Witmer, Bailey, & Knerr, 1995) to fully immersive training and mission rehearsal for squad leaders (Knerr, et al., 2003) most of which showed promise in spatial training and recall for dismounted soldiers. During these studies there were attempts made to classify some of the larger problems with virtual reality environments, particularly combating simulator sickness and creating training that justifies the large cost behind immersive virtual environments (Knerr, 2006). Recent hardware advancements have shown the capability to provide low-cost virtual environments with natural locomotion techniques incorporated (Williamson, Wingrave, LaViola, Roberts, & Garrity, 2011). While an entirely virtual environment offers limitless possibilities for training scenarios, they often come with limitations such as problems with proper spatial awareness while moving around in a limited environment, effectiveness given artificial graphics and potential sickness in a fully immersed world.

Soldier training has shown promise in augmented reality environments, which are capable of maintaining some of the physical characteristics a soldier is used to. As mentioned in (Hughes, Stapleton, Hughes, & Smith, 2005) augmented reality is where interaction with a real setting is assisted by virtual asset augmentation. In that same paper, an evaluation was done of augmented reality training in an urban environment with the MR-MOUT system, particularly how effective augmented reality with realistic audio feedback provided improved performance as a dismounted soldier relies on all of their senses to assess a situation. While that system focused on training in as realistic of a scenario as possible, some systems, such as BARS (Livingston, et al., 2002) focused on providing increased situational awareness to a solder in training via visual cues augmented onto the real world. However augmented reality systems must be aware of their physical surrounding as occlusion is an important aspect of depth perception (Azuma, 1997) and must be shown for any virtual assets placed into a real world scene.

For the scanning and acquisition of a 3D environment, Simultaneous Localization and Mapping (SLAM) algorithms have proven to be very effective. These algorithms were originally developed for robotic vision and mapping of a robot's position, but as shown in research such as (Klein & Murray, 2007) it can be used to track a small camera used in an augmented reality workspace. In (Izardi, et al., 2011) the Kinect Fusion project was explored, which made use of a continuous moving stream of depth sensor frames to generate 3D models. This was expanded over recent years to include the RGB frames as well. In (Endres, Hess, Sturm, Cremers, & Burgard, 2012) the color pixels from RGB frames associated with a depth sensor could be localized in a 3D frame. For scanning of large areas, such as an entire room or the outdoors, the LSD-SLAM algorithm (Engel, Schöps, & Cremers, 2014) could be used. This system showed the capability to use a monocular video camera and SLAM algorithms to create large scale 3D scenes.

We examined ITS research, which was conducted using a virtual reality system to train soldiers, focusing on how the types of feedback (immediate or delayed, directive, supportive or explanatory) affect learning. Jensen, Sanders, Mosley, & Sims (2009) discovered that delayed feedback provided better retention, but immediate feedback resulted fewer procedural errors. We chose to integrate with a CBTS known as the Generalized Intelligent Framework for Tutoring (GIFT) (Sottilare, Goldberg, Brawner, & Holden, 2012). GIFT is a modular tutoring architecture that easily adapts instruction based on the trainee's goals and competency GIFT is driven by a learning effect model which optimizes learning by tailoring interaction with the trainee and the training environment (Sottilare, 2013; Sottilare, 2015). With this intelligent tutoring system we would be capable of easily adapting our training simulations for maximum effect.

3D SCANNING

For the 3D scanning system our goal was to create a 3D model of the setting a soldier would be training in with augmented reality. We also wanted to provide human in the loop scanning which would allow an individual to correct and perfect the model as it is being scanned in, similar to (Miksik, et al., 2015). For this we made use of two commercial off the shelf (COTS) devices, the Structure depth scanning sensor and the Oculus Rift virtual reality device.

The Structure sensor (Occipital Inc, 2015), shown in Figure 2, was chosen as it was light weight and had a range of 3.5 meters along with driver support for software we planned to use and 3D printer ready model attachments available. This sensor provides depth images from dual infrared LEDs, but no RGB data as the Kinect does. We also looked at the Soft Kinetic 3D imaging sensor (SoftKinetic, 2015), which performed well with its depth sensor range, but was a little large and heavier than we wanted.

We attached the Structure sensor to an Oculus Rift (Oculus VR LLC, 2015) also shown in Figure 2 using 3D printable constructs. We chose the Oculus Rift as we wanted a full and clear view of the outside world to be available to the user, rather than the see-through augmented reality devices which tend to lead to translucent images and a smaller field of view. The Samsung Gear VR (Samsung, 2015) was considered, but we did not use it as it required special hardware with a potential subscription plan. The Epson Moverio (Epson, 2015) was also considered, but it did not provide a sufficient field of view for immersion.

Figure 2. An Oculus Rift with a Structure Sensor (blue) attached to the front.

This prototype worked well for the scanning, but would do little to achieve augmented reality as the Oculus Rift is typically used for virtual reality systems and the sensor we chose had no RGB data to display to the user. For this reason we also worked on a prototype that would attach wide field of view webcams to the front of an Oculus where the eyes would normally see as shown in Figure 3. We had difficulty with the initial 3D printed mounting not providing room for the Structure sensor, also it was not secure in its mounting, resulting in wobbly cameras and leading to disorientation for any user. Furthermore, the webcams required a large field of field to seem correct when displayed closely to the user's eyes within the Oculus Rift. For this reason we used different webcams and a more stable mounting that is also shown in Figure 3. We developed an test scene within Unity 3D that could be displayed on the Oculus showing the webcam images to each eye, as shown in Figure 4.

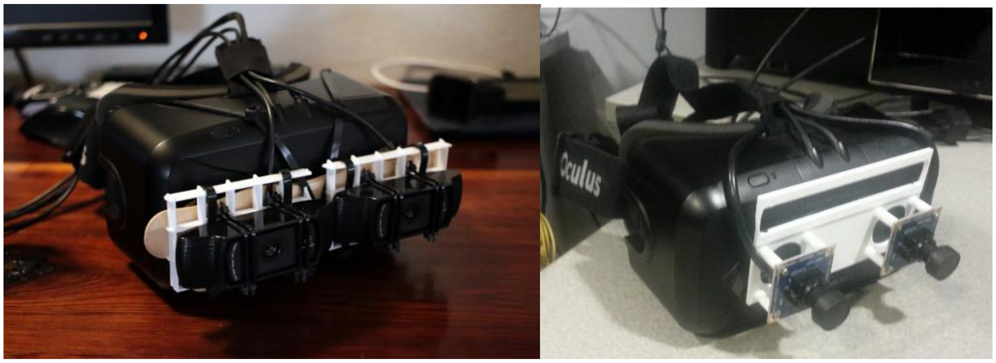

Figure 3. Oculus Rift with original webcams and mounting on the left. Finalized prototype with webcams and improved mounting on the right.

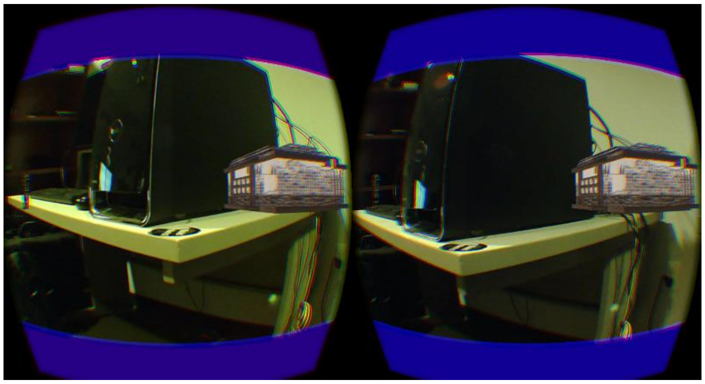

Figure 4. Example of Unity scene that displays webcam images to each eye. Example virtual avatars are loaded to test webcam capabilities.

While developing the software for the Oculus some issues were noticed. The system had to be optimized to reduce any delay between the webcams and the Oculus display, as this could lead to simulator sickness. We tested if the delay was within Unity by creating a simple openGL application which would only place the webcam images in front of the user. We found the openGL application to have the same delay. With this knowledge we proceeded with using Unity 3D as we had minimized the delay as much as possible. We also found that the fixed inter-ocular distance of the webcams could cause difficulty to some users who are not used to seeing the world as spaced out as the cameras were set. For this reason we included an option to just show one webcam's image to both eyes. While this had a detrimental effect on depth perception, it was found to reduce simulation sickness for some users.

For the scanning software we made use of the Point Cloud Library (PointClouds.org, 2015). This open source software system allowed us to scan in room sized areas using their Kinfu large scale research (PointClouds.org - Kinfu, 2015). By taking depth images from a Structure sensor (Occipital Inc, 2015) we were able to supply data to the Kinfu system to reconstruct the room it was tracking in. The depth frames were also used to localize the frame of reference with a SLAM algorithm so that large areas can be scanned in and added to. An example of scanning in a portion of our laboratory room is shown in Figure 5.

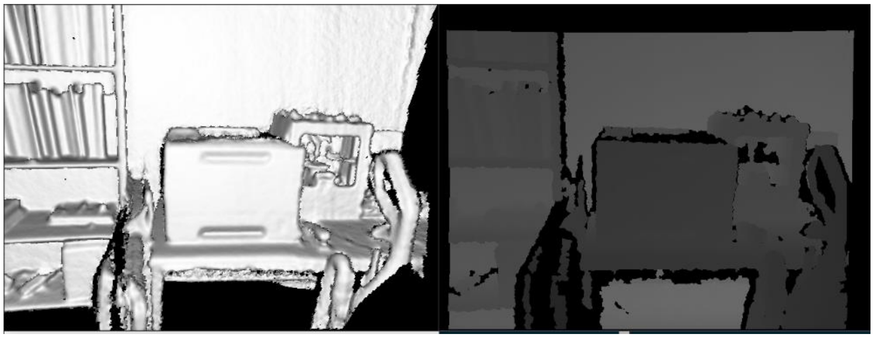

Figure 5. Left screen shows the compiled 3D model created by the Kinfu system. Right screen shows the current depth image.

We found the PCL software to scan well, although is not yet implemented in the headset. It also had issues maintaining tracking if a sudden movement occurred, which will prove problematic when mounted to a user's head, but we have identified potential solutions to implement for re-localization once tracking is lost. Furthermore, there were no options for user interaction to modify the 3D model as it was scanning. The overall vision of our system is to combine the two webcams along with the Structure Sensor so that a user can have an augmented reality interface as the system is scanned. With this interface a user may quickly and easily scan in a large area with the thoroughness they require as they are provided real time vision of the model in an augmented reality interface. This system would also be capable of expansion so that the user may modify the 3D model to their needs while interacting and scanning in the scene.

ARWILD SYSTEM

The ARWILD system made use of the 3D models that were scanned in to develop an augmented reality training scenario that integrates a GIFT-based tutor (Sottilare, Goldberg, Brawner, & Holden, 2012). By using the scanned environment we would be able to provide context of real objects to the virtual ones in the training system. This would also provide awareness of objects a soldier may use to hide behind or utilize in their training.

For the augmented reality system we made use of the Metaio SDK (Metaio GmbH, 2015) in particular their Unity plugin (Unity Technologies, 2015). With this set up we were able to scan in a 3D feature map of the environment so that RGB images could be used for localization of the 3D Unity scene. The feature map utility allows several photos of an environment to be used to create 3D points that the SDK may recognize. Furthermore, these 3D points could be loaded into Unity so that a reference is available when building the virtual scene.

To provide location awareness of virtual objects we had to provide the ability to obscure them behind real objects. For this we used the 3D model that we scanned in of the environment and aligned it with the Metaio feature map. The environment model was given a special shader script that would affect the normal rendering order when viewed by the user. The system then takes the object furthest back, in this case the webcam images, and renders it first as the object's texture. This is followed by any other renderings behind the object, although they are now obscured by the webcam images. An example was created by scanning in a filing cabinet in the laboratory and loading in a virtual soldier next to it. Figure 6 shows the Unity scene setup and Figure 7 shows the soldier being obscured by the scanned in model and being visible once the user walked around the filing cabinet.

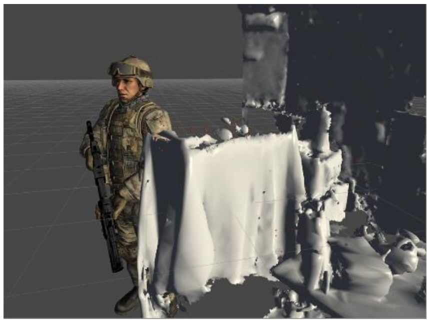

Figure 6. Soldier avatar placed next to scanned in 3D scene from laboratory.

Figure 7. Unity scene displaying obscured virtual soldier on the left and fully visible solder on the right.

For intelligent tutoring we integrated the GIFT system into the AR environment. This modular architecture provided a standard messaging interface, written in XMLRPC, between the learner, sensor, tutor, pedagogy system and the ARWILD module we created. It also provided a GUI interface to the tutor on which modules and courses can be loaded to the learner when available. All information from the client application is sent to the server to be analyzed by the learner and pedagogical modules so that the performance of the user may be used to personalize the learning experience.

As an example of our prototype system we created a simple superior officer protocol training scenario in which the user would approach the virtual soldier and be prompted with options to interact with them. These options would train a potential recruit on how to greet a superior, either with a formal salute or informal greeting and the feedback from their choice would be sent to the GIFT modules which would respond with instant feedback to the user. The purpose of this example was to test the interactions between the GIFT modules and our prototype system. The vision for ARWILD is to expand this to more complicated training scenarios such as threat assessment and mission rehearsal using a fully developed augmented reality environment. An example of the prototype interaction is seen in Figure 8.

Figure 8. An example interaction between the ARWILD system and GIFT modules that shows training in greeting a superior.

CONCLUSION AND FUTURE WORK

In this paper we presented the prototypes of the ARWILD system that is in development and the important problems that we encountered when developing an augmented reality system capable of working in any environment. As we work to resolve these issues the overall system has shown promise for development of training scenarios and integration with GIFT which will be expanded upon in the upcoming year. This paper discussed first steps in moving from desktop simulations to immersive AR systems and ultimately to the wild, locations where there is no training infrastructure. Our AR environment is being used to evaluate scenarios which include psychomotor tasks. The goal is to more closely align intelligently guided instruction with the physical aspects of many Army training tasks.

We plan to work on modifications to the Kinfu system to provide better re-localization if tracking is lost and to develop real time modifiable 3D models. Furthermore this system will be presented to the user in an augmented reality interface so that human-in-the-loop creation is possible. This will allow easy editing of acquired 3D scenes as a user can focus on objects of importance to their scenarios or areas where the scanning algorithms have made mistakes in real time.

The Kinfu system will also be modified to provide localization in real time for the ARWILD training scenarios. With this system we will remove the sections that use the depth images to create a 3D model and instead focus on using the depth images to provide location coordinates to the system. This system can be combined with Metaio's 3D mapping references so that the two sources of location data can be fused for better accuracy.

Finally the ARWILD system will be expanded to include a complex training scenario such as threat assessment and mission rehearsal which is monitored by a GIFT-based tutor. Using this we will evaluate the system and provide detailed data of the simulations.

We have found that our ARWILD prototype is capable of using commercial off the shelf systems and software to create augmented reality systems with potential to train dismounted soldiers. While this is in the initial prototype stage, the research done so far suggests strong potential for this system in the future. With the solutions being developed for the problems explored in this paper, the ARWILD system will prove capable of easily integrating ITSs with any real world environment for in-the-wild immersive training.

REFERENCES

Azuma, R. (1997). A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments, 6*(4), 355-385.

Endres, F., Hess, J., Sturm, J., Cremers, D., & Burgard, W. (2012). 3D Mapping with an RGB-D Camera. *IEEE Transaction on Robotics, 30*(1).

Engel, J., Schöps, T., & Cremers, D. (2014). LSD-SLAM: Large Scale Direct Monocular SLAM. *European Conference on Computer Vision.* Zurich: Springer.

Epson. (2015, May 30). *Epson Moverio*. Retrieved from Epson Web Site: http://www.epson.com/cgi-bin/Store/jsp/Landing/moverio-bt-200-smart-glasses.do

Goldberg, B., Sottilare, R., Brawner, K., & Holden, H. (2012). Adaptive Game-Based Tutoring: Mechanisms for Real-Time Feedback and Adaptation. International Defense & Homeland Security Simulation Workshop in Proceedings of the I3M Conference. Vienna, Austria, September 2012.

Hughes, C. E., Stapleton, C. B., Hughes, D. E., & Smith, E. M. (2005). Mixed Reality in Education, Entertainment, and Training. *Computer Graphics and Applications, 25*(6), 24-30.

Izardi, S., Kim, D., Hilliges, O., Molyneaux, D., Newcombe, R., Kohli, P., . . . Fitzgibbon, A. (2011). KinectFusion: Real Time 3D Reconstruction and Interaction Using a Moving Depth Camera. *UIST* (pp. 559-568). Santa Barbara: ACM.

Jensen, R., Sanders, M., Mosley, J., & Sims, J. (2009). Intelligent Tutoring Methods for Optimizing Learning Outcomes with Embedded Training. *NATO HFM.* Orlando.

Klein, G., & Murray, D. (2007). Parallel Tracking and Mapping for Small AR Workspaces. *Mixed and Augmented Reality* (pp. 225-234). Nara: IEEE.

Knerr, B. W. (2006). Current Issues in the Use of Virtual Simulations for Dismounted Soldier Training. *NATO.* West Point.

Knerr, B. W., Lampton, D. R., Thomas, M., Comer, B. D., Grosse, J. R., Centric, J. H., . . . Washburn, D. A. (2003). Virtual Environments for Dismounted Soldier Simulation, Training, and Mission Rehearsal: Results of FY2002 Culiminating Event. *Army Research Institute Technical Report*.

Livingston, M. A., Brown, D., Gabbard, J. L., Rosenblum, L. J., Baillot, Y., Julier, S. J., . . . Hix, D. (2002). An Augmented Reality System for Military Operations in Urban Terrain. *I/ITSEC.* Orlando.

Metaio GmbH. (2015, May 20). *Metaio SDK*. Retrieved from Metaio Website: http://dev.metaio.com/sdk/getting-started/

Microsoft. (2015, May 20). *Kinect for Windows SDK*. Retrieved from Micorosft Website: https://www.microsoft.com/en-us/kinectforwindows/

Miksik, O., Vineet, V., Lidegaard, M., Prasaath, R., Nießner, M., Golodetz, S., . . . Torr, P. H. (2015). The Semantic Paintbrush: Interactive 3D Mapping and Recognition in Large Outdoor Spaces. *Conference on Human Factors in Computing Systems* (pp. 3317-3326). ACM.

Occipital Inc. (2015, May 20). *Structure Sensor*. Retrieved from Structure Sensor Website: http://structure.io/

Oculus VR LLC. (2015, May 20). *Oculus Rift*. Retrieved from Oculus Rift Website: https://www.oculus.com/

PointClouds.org - Kinfu. (2015, May 20). *Using Kinfu Large Scale to Generate a Textured Mesh*. Retrieved from PCL Website: http://pointclouds.org/documentation/tutorials/using_kinfu_large_scale.php

PointClouds.org. (2015, May 20). *PCL - Point Cloud Library*. Retrieved from PCL Website: http://pointclouds.org/

Samsung. (2015, May 30). *Samsung Gear VR*. Retrieved from Samsung Web Site: http://www.samsung.com/global/microsite/gearvr/

SoftKinetic. (2015, May 30). *SoftKinetic Depth Sense Cameras*. Retrieved from SoftKinetic Web Site: http://www.softkinetic.com/Products/DepthSenseCameras

Sottilare, R. (2013). Special Report: Adaptive Intelligent Tutoring System (ITS) Research in Support of the Army Learning Model - Research Outline. *Army Research Laboratory* (ARL-SR-0284), December 2013.

Sottilare, R. A., Goldberg, B. S., Brawner, K. W., & Holden, H. K. (2012). A Modular Framework to Support the Authoring and Assessment of Adaptive Computer-Based Tutoring Systems (CBTS). *I/ITSEC.* Orlando.

Sottilare, R. & Gilbert, S. (2011). Considerations for tutoring, cognitive modeling, authoring and interaction design in serious games. In Proceedings of Authoring Simulation and Game-based Intelligent Tutoring Workshop at the Artificial Intelligence in Education Conference (AIED) 2011, Auckland, New Zealand, June 2011.

Sottilare, R., (2015). Challenges in Moving Adaptive Training & Education from State-of-Art to State-of-Practice. In Proceedings of the “Developing a Generalized Intelligent Framework for Tutoring (GIFT): Informing Design through a Community of Practice” Workshop at the *17th International Conference on Artificial Intelligence in Education (AIED 2015)*, Madrid, Spain, June 2015.

Unity Technologies. (2015, May 20). *Unity Game Engine*. Retrieved from Unity Website: https://unity3d.com/

Williamson, B., Wingrave, C., LaViola, J. J., Roberts, T., & Garrity, P. (2011). Natural Full Body Interaction for Navigation in Dismounted Soldier Training. *I/ITSEC.* Orlando.

Witmer, B. G., Bailey, J. H., & Knerr, B. W. (1995). Training Dismounted Soldiers in Virtual Environments: Route Learning and Transfer. *Army Research Institute Technical Report*.