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# Mission Specific Embedded Training Using Mixed Reality

## Abstract

High risk special operations often require that the team is trained in advance in an environment similar to the target area. It would be ideal if a replica could be built and the team could be trained in the operational environment. However, it is usually difficult to do so in a timely manner, especially when intelligence constantly changes. Traditionally, a scaled-down model of the target area is built instead. Mixed reality based embedded training with the ability to rapidly build and improve the model is a useful tool that can meet these challenges.

Several research groups have considered augmented reality (AR) or mixed reality as a training tool for military operations in urban terrain. Our group has developed the Battlefield Augmented Reality System (BARS$^{TM}$), which can be used for a variety of applications, such as situation awareness as well as embedded training. We have since developed a new version of the system that makes use of the state-of-the-art techniques to build mission-specific training systems in a timely manner. While there is still debate on how effective a current AR situation awareness system is in an actual combat situation, we have seen increased interest in AR training among Marines, Air Force special forces, and others.

In this paper, a mission specific embedded military training system using mixed reality is presented. The methods for building environmental models and embedding synthetic characters are described. A set of tools has been assembled to build mission specific models. These models together with a modular physical setting can be integrated into the training system which provides a mixture of virtual objects and physical objects. This mixed environment provides a more realistic training than a pure virtual environment, and more flexible training than pure physical settings.

## 1 Introduction

To ensure the success of high risk special operations, it is often required that the special operation team is trained in advance in a environment similar to the target area. It would be ideal if a physical replica could be built and the team could be trained in the environment. However, it is usually difficult to do so in a timely manner, especially when the intelligence is constantly changing. Traditionally a scaled down model is built instead. This has a negative impact on planning and training. A mixed reality (MR) based embedded training system with the ability to rapidly build and improve the model is proposed in this paper to meet these challenges.

Several groups have considered augmented reality (AR) or mixed reality as a training tool for military operations in urban terrain [1, 2]. Our group has developed a system, the Battlefield Augmented Reality System (BARS$^{TM}$) [3], that can be used for a variety of applications, such as situation awareness[4] as well as embedded training [5]. We have since developed a new version of the system that makes use of the state-of-the-art technique to build mission specific training systems in a timely manner. With the ability to build and update the model of the target area within hours, the system is a useful tool for the training of special operations. While there is still debate on how effective a current AR situation awareness system is in an ac-

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14. ABSTRACT

**High risk special operations often require that the team is trained in advance in an environment similar to the target area. It would be ideal if a replica could be built and the team could be trained in the operational environment. However, it is usually difficult to do so in a timely manner, especially when intelligence constantly changes. Traditionally a scaled-down model of the target area is built instead. Mixed reality based embedded training with the ability to rapidly build and improve the model is a useful tool that can meet these challenges. Several research groups have considered augmented reality (AR) or mixed reality as a training tool for military operations in urban terrain. Our group has developed the Battlefield Augmented Reality System (BARSTM), which can be used for a variety of applications, such as situation awareness as well as embedded training. We have since developed a new version of the system that makes use of the state-of-the-art techniques to build missionspecific training systems in a timely manner. While there is still debate on how effective a current AR situation awareness system is in an actual combat situation, we have seen increased interest in AR training among Marines, Air Force special forces and others. In this paper, a mission specific embedded military training system using mixed reality is presented. The methods for building environmental models and embedding synthetic characters are described. A set of tools has been assembled to build mission specific models. These models together with a modular physical setting can be integrated into the training system which provides a mixture of virtual objects and physical objects. This mixed environment provides a more realistic training than a pure virtual environment, and more flexible training than pure physical settings.**

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tual combat situation, we have seen a lot of interest in AR training among Marines, Air Force special forces, and so on.

Among the most recent efforts on AR/MR military applications, the DARPA sponsored Urban Leader Tactical Response, Awareness and Visualization (ULTRA-Vis) project is targeted to giving small unit leaders the capability to issue commands and share actionable mission-relevant information in an urban environment non-line-of-sight.[6] AR/MR has also found other applications in military training, such as a virtual sand table[7], armored personnel carrier turret maintenance[8], and infantry skills training[9].

In this paper, a mission specific embedded military training system using mixed reality is presented. The methods for building environmental models and embedding synthetic characters are described.

# 2 Methods

The mixed reality based mission specific embedded training system is developed on top of a general AR embedded training system. An MR system is a complex system that has many hardware and software components: a tracking component, a display component, user interface, world model, etc. In addition to the components that are common in mixed reality training systems, the ability to create mission specific environmental models rapidly and insert synthetic characters based on requirements of the mission are two main aspects that are unique to BARS™.

A set of tools has been assembled in BARS™to build mission specific models. These models, together with a modular physical setting, can be integrated into the system which provides a mixture of virtual objects and physical objects. This mixed environment provides a more realistic training than a pure virtual environment, and more flexible training than pure physical settings. Synthetic characters are included in the system; their behavior can be programmed to mimic the enemy forces or other entities that are more convenient to control digitally. For example, the system can be used to train how to behave in a manner compatible with cultural norms. The actors could become more cooperative as a reward for proper behavior or more hostile as a cost of inappropriate behavior.

## 2.1 Environmental Modeling

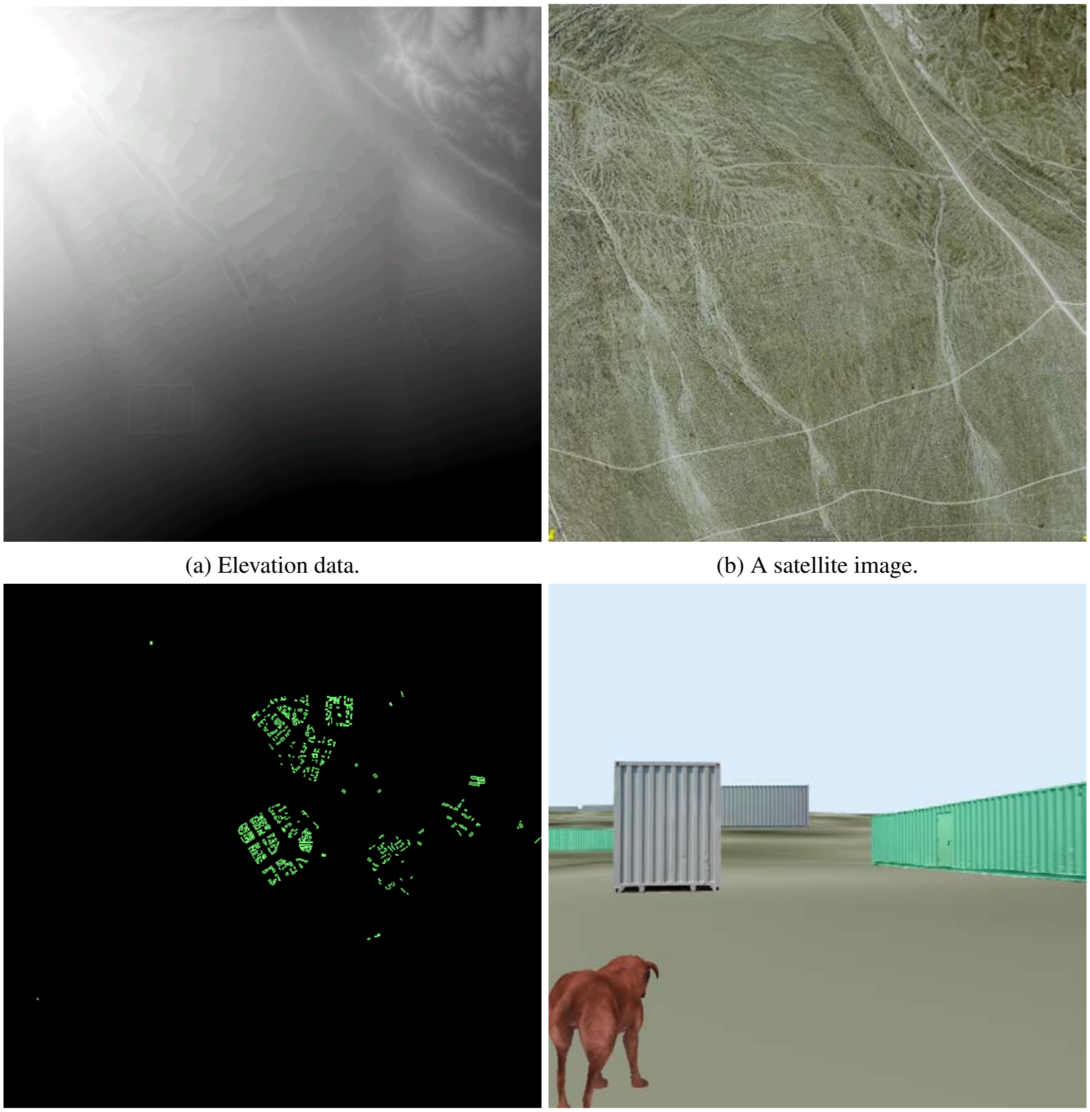
The environmental models are built using data from various sources, depending on the availability of the intelligence. In general, three different source data are used in our study. Digital elevation maps are used to define the shape of the terrain, images that show the texture of the ground are used to render the background, and building maps are used to define the shape of the buildings. In some applications, detailed building models may be required.

Satellite images and digital elevation data are used to build the terrain model. Light Detection And Ranging (LIDAR) data of the buildings are used as initial template to build models of the buildings. These geo-referenced data sets are automatically or semi-automatically integrated, while other details are added manually based either on intelligence or assumptions.

The modeling workflow is shown in Figure 1 and depicts the environmental model. The environmental model consists of a terrain model and a building model. The terrain model is built based on digital elevation data (Figure 1 (a)), which usually is a GeoTIFF file, and satellite images (Figure 1 (b)) that are used as textures.

Several open source or freely available software tools are used to create the terrain model. Usually some artifacts are present in the digital elevation GeoTIFF file, and a pre-processing step is needed. FWTools[10] is used for pre-processing, including cropping, geo-information extraction, etc. It is also used to extract geo-tag information that will be used in further steps.

Satellite images or aerial photo images are useful when creating the texture of the ground. One convenient source of satellite images is Google Earth or Google Maps. These satellite images are used as texture maps in building the terrain model. To extract satellite images from Google Earth, placemarkers are placed at the four corners with the same coordinates of the GeoTIFF file of the digital elevation data. Google Earth only allows input of latitude/longitude data; thus, coordinate system conversion is needed. The captured images need to be cropped using image processing software. To



(a) Elevation data.

(b) A satellite image.

(c) Building shapefile.

(d) 3D model in the training environment.

Figure 1: Modeling the Environment.

capture high-resolution texture images, some kind of stitching methods need to be used. One possibility is to use Google Maps API to get high-resolution images.

The geo-referenced information in the digital elevation data needs to be transferred to the texture map. This can make sure that the two data will align with each other. Satellite images and digital elevation data are combined using an open source tool called VirtualPlanetBuilder[11].

Compared to environmental models, the process of creating building models is more complicated. Although tools such as VirtualPlanetBuilder should have the ability to create models from a shapefile, the functions are often not working well. A different set of tools are used in our study. The shapefile (Figure 1 (c)) is first converted to a 3D model using a geographic information system (GIS) software. It is important to make sure that the base heights match the digital elevation data. The base heights information in the shapefile may not agree with the information in the elevation file.

The created 3D model file can be imported into a 3D modeling software to do modification, texture mapping, and adding other objects, etc.

The terrain and the building are combined into the MR simulation environment (Figure 1 (d)). It is very important to keep the alignment among dif-

(a) Synthetic characters in an indoor environment. (b) Synthetic characters in an outdoor environment.

Figure 2: Embedded training with augmented reality.

ferent models. The terrain model is in the coordinate system that was defined in the geo-tags. When the building model is created from the shapefile, it might be in a different coordinate system. The offset between the building and the terrain should also be calculated.

## 2.2 Actor Modeling and Artificial Intelligence

Opposing forces can also be digitally built in the system. The behavior of the synthetic characters in this training environment is controlled by an artificial intelligence (AI) module. It is further programmed with a scripting language.

The intelligence of the synthetic actors are designed in two levels. First, a navigation system is implemented so that the actors can navigate automatically in the scene when a target position is designated. Secondly, the behavior of the characters is controlled by a two-stage state machine.

The top level state machine works at mission level. It controls how a character acts when it receives a certain command. It also controls the response when it encounters a certain event. For example, when a soldier actor hears an explosion, the state machine can decide to send it to investigate the incident or search for cover. In each state in this top level state machine, there is a second state machine. This secondary state machine controls the low level animation sequence of the character.

Figure 2 shows the synthetic actors in the MR environments, indoor and outdoor.

Two approaches have been implemented to include animated characters into the system. One is using DI-Guy software development kit, which is developed by Boston Dynamics. The other approach is an open source approach. It uses a 3D character animation library, Cal3D.[12]

BARS™can also connect to the US Army's OneSAF Testbed Baseline Semi-Automated Forces (OTBSAF) system to use computer-generated forces. The system connects to a local instance of the Run-Time Infrastructure (RTI) which OTBSAF also connects through a gateway. The users are reflected in real time in OTBSAF as friendly forces, and the computer-generated forces respond appropriately. These responses are sent to the training system to control the visualizations of the computer-generated forces.[2]

## 2.3 Implementation

BARS™includes a tracking component, a display component, a network component, a database component, and an AI/animation component (Figure 3). The tracking component is a generalized driver that supports a variety of hardware sensors, such as GPS, inertial, acoustic, optical sensors, etc. These sensors can be dynamically assigned to track the position and orientation of the user and/or the position and orientation of a weapon. The display component supports head-worn-display, both optical see-through or video see-through. The network component allows multi-user training in a networked environment. The database component

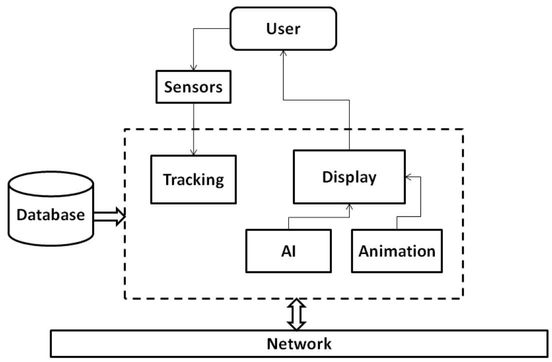



Figure 3: BARS system diagram.

can import models from different sources.

The software system is implemented around a open source game engine, Delta3D[13], which uses a OpenGL based open source toolkit, OpenSceneGraph[14] for rendering. A mobile version of the system makes use of portable computers to assemble the system into a backpack. A wireless network provides communication among different mobile systems.

## 3 Conclusion

This paper described a mixed reality method for military training that incorporates mission specific environmental models and digital opposing forces and other synthetic characters. A workflow has been developed to create the environmental model quickly and can be modified easily based on the constantly changing intelligence. These models together with a modular physical setting can be integrated into a system that provides a mixture of virtual objects and physical objects. This mixed environment provides a more realistic training than a pure virtual environment, and more flexible training than pure physical settings.

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