The Wide Area Virtual Environment - A Novel Immersive Environment for Medical Team Training

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Abstract. Medical simulation presents a viable alternative to traditional methods of medical instruction, such as cadavers and animal models. Simulation can provide safe, consistent, and repeatable learning opportunities. It accomplishes this without risk to patient safety. There is an increasing awareness of the value that simulation brings to learning. The Wide Area Virtual Environment (WAVE) is an 8,000 sq. ft. immersive virtual reality facility intended to support medical team instruction. It is the world's largest immersive virtual environment. The WAVE represents a novel application of human-computer interaction. It forms the basis for a synergistic amalgamation of live, virtual, and constructive simulation for medical instruction. This paper describes the motivation behind the WAVE. We also describe the WAVE's primary components, and how they are used during a learning scenario. Our experience with using the WAVE is also described.

Keywords: Immersive reality · Medical simulation · Medical team training

1 Introduction

Simulation is an established component of modern medical instruction. Medical simulation modalities can be broadly divided into three categories: part task trainers, standardized patients, and virtual-reality trainers. Part task trainers are designed to facilitate the practice of specific medical or surgical skills. Standardized patients are trained individuals who have been taught to exhibit the characteristics of real patients. Standardized patients can be deployed in settings where patient examinations must be taught. Virtual-reality trainers present computer-generated scenarios geared toward developing cognitive and dexterous skills. These scenarios can include situations that would otherwise present injury or damage to standardized patients or human patient simulators. An example would be performing a laparotomy.

The Wide Area Virtual Environment (WAVE) is an 8,000 sq. ft. facility designed to present an immersive virtual environment for medical team training. The WAVE is a novel learning platform. It integrates all three simulation modalities to present a unique setting for medical team learning. In the next section, we describe the motivation for developing the WAVE.

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2 Background

The practice of medicine requires knowledge, skills, and experience. Knowledge can be acquired through classroom learning, but skill and experience require practice. The apprenticeship model continues to play a significant role in medical education. [1]. Learners study under experienced practitioners and assist in treatment. This model has disadvantages. The risk to patients from inexperienced learners can be high. This instructional model can be considered as opportunistic learning. The student practices on whatever patient comes into the clinic. Common cases receive more exposure while rare cases may not be studied at all.

To reduce the risk of harm, cadavers and animal models substituted for live patients. While an improvement over practicing on live patients, they have disadvantages. Cadavers can be difficult to procure and do not have a viable physiology. Animals cannot fully replicate human anatomy. Their use also raises ethical concerns.

Modern medical simulation addresses many of these limitations. Three main categories of simulations are in common use: part task trainers, standardized patients, and virtual-reality trainers.

Part task trainers permit learners to focus on practicing specific medical skills. E.g., performing a cricothyroidotomy [2]. Because of their specificity, part task trainers often do not incorporate the full anatomy. The physiological effects of treatment are usually not simulated. Human patient simulators (HPS) evolved to address this shortcoming. HPS are computer-controlled mannequins instrumented to exhibit physiological responses. For example, they can breathe, have a detectable heartbeat and pulse, speak, and have pupils that respond to light. Many of them are self-contained, and incorporate battery packs and wireless data interfaces to allow remote operation.

Standardized patients (SP) are individuals recruited and trained to exhibit characteristics consistent with a live patient. Standardized patients are often used to facilitate medical instruction in a clinical setting. For example, they are used to educate clinicians on the appropriate techniques to examine a patient, and to conduct medical interviews. Standardized patients can also be moulaged to simulate the appearance of traumatic injuries. Thus, they can also be used for rehearsing triage in a mass casualty scenario.

Unlike part-task trainers and standardized patients, virtual reality trainers generally do not use a physical representation of the patient. Instead, learners interact with a virtual human within a computer system. Depending on the application, tactile senses can be replicated using haptic interface devices [3] while 3D displays provide the illusion of depth. The Haptic Workbench [4] is an example of a virtual trainer with medical applications (e.g. [5]).

Despite their individual success, there has been few attempts to combine modalities. [6] described using an HPS within a CAVE environment. [7] incorporated virtual avatars that serve as guides to the learner within a surgical environment. Integration was done at a small scale, and only involved two of the three modalities. Frequently, these attempts provided instruction only to a single learner. Limited effort has been made to integrate all three modalities for medical team instruction.

The WAVE addresses these shortcomings. It combines live action (standardized patients), part task trainers, and immersive virtual environments for medical team training in arbitrary settings that can last several hours. This is discussed in the next section.

3 Methods

The WAVE is an immersive virtual reality theater for medical team training. The WAVE seeks to combine all three modalities commonly used in medical simulation. In this section, we describe the layout, operation, and design of the WAVE.

3.1 Layout

The WAVE is comprised of 24 screens forming two circular pods connected by a corridor. Each pod is approximately 25 ft. in diameter. The corridor is 20 ft long. The corridor tapers from 12 ft. at each end to 9 ft. in the middle. Within the WAVE, learners wear lightweight passive stereo glasses. They perceive an immersive and immersive 3D virtual environment while moving freely within the space. During a training exercise, the WAVE incorporates standardized patients, part task trainers, and lightweight props to simulate actual environments where a medical team can be deployed. E.g., combat or civilian mass-casualty, natural disaster, and chemical/biological/nuclear scenarios. Access to the WAVE is via an entrance in each pod. Each entrance is made up of two screens pivoted to swing outward. During use, they are closed to present a seamless environment. Figure 1 illustrates.

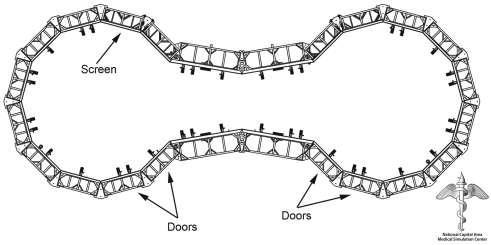

Fig. 1. WAVE layout

3.2 Concept of Operation

The WAVE is designed to support training activities lasting many hours. The nature and scope of the environment changes as the scenario progresses. This is accomplished by changing both virtual and physical environmental elements. Each pod is used alternately as training progresses. The unoccupied pod undergoes reconfiguration in anticipation of the next step in the exercise. A hypothetical scenario is described.

In this example, learners enter Pod A (left) to rescue injured warfighters. The wounded may be portrayed by SPs or HPS, depending on training objectives. As the

injured are treated, the team encounter hostile fire from virtual enemies. They respond by returning fire while the medic performs first aid. The team repels the attack and calls for air evacuation.

While learners are engaged in Pod A, Pod B (right) is being prepared for the next step of the scenario. A mobile motion platform is setup in Pod B with a mockup of a UH-60 helicopter. As the medical team in Pod A prepares the patients for transport, the center curtain lifts. The team physically transports and loads the patients into the UH-60. The scenario continues into the air evacuation phase of the exercise. The medical team provides care while inflight. The WAVE generates imagery consistent with helicopter flight while the motion platform matches the visualized flight characteristics.

During this time, Pod A is reconfigured so it no longer depicts the IED attack scene. Physical props such as road barriers and debris are removed and the visual imagery is changed. Medical equipment consistent with that used in a forward operating base is moved in and a 3D virtual field hospital, complete with animated avatars and sound effects is rendered in the WAVE. By the time the UH-60 lands, learners moving back into Pod A see a completely different scene. This process of alternating between pods during an ongoing scenario allows training to continue indefinitely.

3.3 Visual and Audio Rendering

The WAVE uses an array of back-projected screens to generate 3D stereoscopic images. The display components are modular. Each module consists of a screen, a pair of projectors, and a pair of image generators. Each screen is back-projected by two 15,000 ANSI lumens projectors. Light from each projector is circularly polarized to facilitate 3D viewing. To optimize space usage, projectors are mounted above the screen and pointing backwards. A large, front-silvered mirror in the rear reflects projected light back to the screen. Figure 2 illustrates. Each projector is driven by one image generator. It comprises of a commercial off-the-shelf computer with a consumer graphics card (NVidia GTX 1080 at the time of writing). The WAVE is assembled from 24 display modules: 10 in each pod and four in the corridor. Screens serving as doors are hinged. They are also supported by wheels to facilitate movement. Wheel positions are indexed relative to the floor to ensure consistent screen positioning.

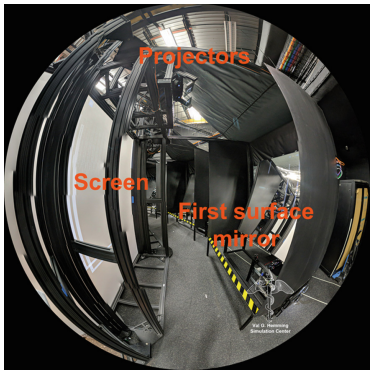

Fig. 2. WAVE module

Audio rendering enhances the realism of the immersive display. Sound effects consistent with the training scenario is generated during training. Audio rendering in each pod is accomplished by a seven-speaker system arranged in a ring above the display modules. Both ambient and directional sounds can be rendered. In addition, a 3 Kw subwoofer is positioned above each pod and above the center of the corridor. These speakers provide subsonic effects. E.g., the percussive effects of a nearby explosion.

4 Results

The WAVE has been in continuous operation since 2012. The WAVE supports the Uniformed Services University of the Health Sciences. It also supports the training requirements of regional military and federal emergency response teams. Smaller systems, termed WAVElets, have been deployed by the Army, Air Force, and Navy. Numerous military as well as civilian emergency response scenarios have been developed. Examples include: Point of injury (military and civilian), chemical release (military), improvised explosive devices, vehicular mass casualty, active shooter, and chemical agent release in public venues.

Figure 3 (left) illustrates a vehicular mass casualty scenario. Multiple injured victims are depicted by standardized patients. The WAVE depicts a much larger casualty field. The noise of emergency vehicles and the cries of the injured deliberately add to the noise and confusion consistent with such a scenario. Figure 3 (right) depict a Forward Surgical Base (FSB) scenario. Here, a medical team works on a human patient simulator configured to simulate blast injuries to the lower body. The WAVE generates an environment consistent with an FSB. Virtual characters depict other medical teams treating additional injured patients.

Fig. 3. Civilian (left) and military (right) WAVE scenarios.

5 Discussion

There are three broad categories of medical simulation: Part task trainers, standardized patients, and virtual reality trainers. These modalities are generally used in isolation. In contrast, the WAVE combines all three modalities in a tightly integrated approach. The WAVE is uniquely suited for capstone exercises, i.e., training events requiring learners to apply everything learned during the course under realistic, often stressful conditions. Unlike field exercises, the WAVE delivers exercises that are more flexible and at a lower cost. Since the WAVE is a controlled environment, exercises can be halted, repeated, or re-started at arbitrary points as required. This capability improves learning by allowing the team to focus on shortcomings discovered in real-time. The WAVE is also well suited for mission specific training. E.g., in hostage rescue situations where familiarity with a specific setting may be critical to success.

6 Conclusion

The WAVE is a novel simulation platform for medical team training. It combines the three primary modalities of medical simulation to produce a unique learning environment. The WAVE's twin-pod configuration facilitates training exercises of an indefinite duration. The WAVE well suited for training specialized medical teams in difficult to replicate scenarios.

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