SAN098-2533C

BIOSIMMER: A VIRTUAL REALITY SIMULATOR FOR TRAINING FIRST RESPONDERS IN A BW SCENARIO

Sharon A. Stansfield Daniel M. Shawver Annette L. Sobel

Sandia National Laboratories
Albuquerque, NM

ABSTRACT

BioSimMER (Bioterrorism Simulated Medical Emergency Response) is a Virtual Reality-based mission rehearsal and training environment. BioSimMER employs contingency-oriented, multiple-path algorithms and MOEs/MOPs focused on real-world operations. BioSimMER is network-based and immerses multiple trainees in a high resolution synthetic environment, including virtual casualties and instruments that they may interact with and manipulate. Trainees are represented as individuals by virtual human Avatars. The simulation consists of several components: virtual casualties dynamically manifest the symptoms of their injuries and respond to the intervention of the trainees. Agent transport analysis is used to simulate casualty exposures and to drive the responses of simulated sensors/detectors. The selected prototype scenario is representative of combined injuries anticipated in BW operations.

A. INTRODUCTION

This paper presents a prototype virtual reality (VR) system for training first responders. The initial application is to medical emergency response and focuses on the training of personnel who might be called upon to provide emergency triage at the scene of an act of terrorism involving both an explosion and the release of a BW biotoxin. The system consists of an immersive, multi-modal user interface and a dynamic casualty model that both changes over time and responds to the actions of the trainee. The system is built upon Sandia's open, distributed VR platform and builds upon previous work in VR-based training of battlefield medics responding to conventional injuries[11]. This platform allows multiple users (displays, trackers, etc.) and multiple, heterogeneous simulation modules to be networked together to create a common, shared virtual environment. A dynamic casualty simulation provides realistic cues to the patient's condition (e.g. blood pressure and pulse change over time as a patient's condition worsens.) The casualty simulation also responds to the actions of the trainee (e.g. a change in the color of a patient's skin may result from a check of the capillary refill rate.) Our current prototype addresses conventional injuries (head trauma and tension pneumothorax), exposure to the biotoxin SEB, and a symptomatic psychological case. Such a scenario is representative of combined injuries anticipated in BW operations.

B. APPLICATION DESCRIPTION

BioSimMER is targeted primarily at training emergency response personnel whose responsibility is to triage and stabilize multiple casualties at the scene of an incident for subsequent transport to hospitals where they will receive focused medical care. This focus differentiates BioSimMER from other VR-based medical trainers[2,5,7] whose primary goal is to train a specific procedure or task. Such systems provide highly realistic anatomical visualizations and/or multi-modal interfaces that address the visual and haptic cues involved in carrying out specific procedures utilizing appropriate medical instruments. The goal of the BioSimMER trainer, in contrast, is to train rapid situational assessment and decision-making under highly stressful conditions. Thus, BioSimMER looks to train the medic not to insert an IV but rather to understand the circumstances under which an IV is

DISCLAIMER

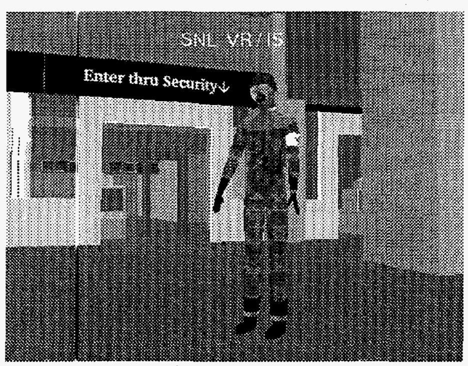
required. The former is referred to as partial task training, while the latter is referred to as situational training. Of course, there is no reason why partial task trainers could not be incorporated into the BioSimMER system.

The adage "practice makes perfect" is quite apropos to situational training. Lectures, books, videos, etc. are no substitute for hands-on experience -- we often learn more from our mistakes than from our successes. Unfortunately, it is difficult to provide such training for large-scale emergency medicine – especially when weapons of mass destruction, such as biological or chemical agents, are involved. Current methodology[8] is to use live training exercises: medics practice stabilization and wound care on animals (e.g. producing a gunshot wound in a goat) or via *moulage* (a training exercise where live participants are given highly realistic "fake" wounds). The shortcoming with the latter is that the medic does not get to practice wound care, while with the former it's the growing concern over using animals for such purposes. Virtual Reality has the potential to augment current training by providing a dynamic, hands-on simulation of a disaster environment with casualties that both manifest the physiology of a given injury dynamically over time and who respond, positively or negatively, to the medic's actions. BioSimMER is a prototype of such a trainer.

1. The Scenario

BioSimMER's initial training scenario is the following: Terrorists have taken over a small airport and are holding hostages. They claim to have released a BW agent, but they do not indicate what. After a several hour stand-off, there is an assault on the airport. The terrorists set off an explosive device, causing conventional injuries and, potentially, additional dispersion of the unknown agent. The trainees enter the scenario at the point just after the assault and explosion. The graphical model of the airport and the trainee avatar in MOPP gear are shown in Figure 1.

FIGURE 1
Airport Model and Avatar



2. START Triage

BioSimMER's initial training procedure is the Simple Triage and Rapid Treatment[3] (START) system. This is the first stage of triage and is carried out for all injury types. START involves evaluating respiration, circulation and the mental status of the casualty. Based upon these assessments patients are put into one of four categories. After all patients have been assessed using START, then medical treatment begins. In the case of a suspected chemical or biological agent exposure, two additional tasks must be performed for each patient: protective breathing apparatus must be applied and the casualty must be decontaminated.

C. BIOSIMMER SYSTEM DESCRIPTION

BioSimMER is built upon Sandia's open, distributed VR platform. This platform allows multiple users (displays, trackers, etc.) and multiple, heterogeneous simulation modules to be networked together to create a common, shared virtual environment. It has been the basis for multiple prototype training systems addressing situational training and action-consequence awareness[9,10,11]. Below, we describe each component in greater detail.

1. The VR Interface

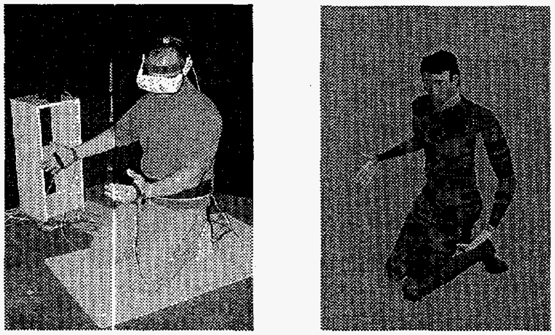
The VR interface for BioSimMER is immersive, the medic/trainee wears a headmounted display and a set of four position trackers (on the head, the lower back, and each hand.) The system is capable of supporting multiple trainees. The primary interface modules are:

a. **VR_Station:** the display driver for the user. Trainees each have an instance of VR_Station that allows them to independently control their viewpoint and motion within the virtual world. Real-time updates of the view of objects in the world are remotely driven by position trackers worn by the user.
b. **Tracker input modules:** obtain the positions of the trackers worn by all users and provide this information to other modules that require it. For example, each VR_Station utilizes the position of the user's head tracker to update his/her view of the world. The avatar driver (see Section C.2) utilizes all four trackers worn by a user to update the position and posture of that user's graphical body.
c. **VR_Multicast:** permits all simulation and interface modules to share information concerning the state of objects (including users) within the simulation environment. VR_Multicast is implemented using Ethernet multicasting of UDP datagrams on a local area network (LAN).
d. **Voice Recognition:** BioSimMER contains a voice recognition component that permits the user to request information, such as vitals; to speak to the virtual casualty; and to command certain actions.

2. The Medic Avatar and Virtual Object Manipulation

Small team situational training applications, such as BioSimMER, require that participants be represented within the virtual environment with a much higher fidelity than do other applications. It is important, for example, that team members be able to see each other as full human figures. Position, posture, gesture and body language are all vital components of team coordination and communication. Figure 2 shows a user and his graphical representation, or avatar. The avatar driver used for this work was developed at Sandia National Laboratories[4]. It combines several techniques: general-purpose kinematic solutions are first generated using the inputs of the four sensors worn on the user's body. Special heuristics are then applied to prune the number of solutions down to one that is reasonable.

FIGURE 2
A User and His Avatar

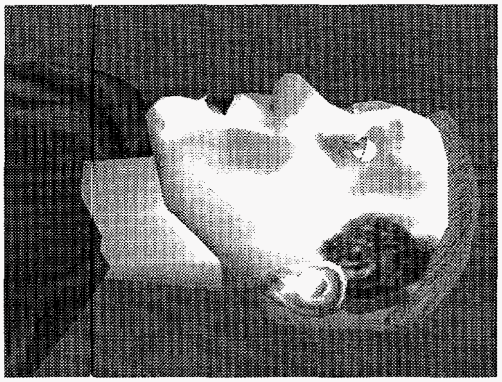


Heuristics are based on knowledge of the human body and of the probable motions of limbs (e.g. where an elbow is more likely to be positioned when a user is waving.) The Avatar also acts semi-autonomously during certain motions requiring fine manipulation. For example, when a user reaches for and grasps an object, the motion and placement of the arm is controlled by the user. The Avatar's hand posture, however, is selected automatically based on the object that the user is trying to grasp. The virtual objects also contain knowledge and use this to aid the user. For example, protective gloves place themselves on the user's hands when they are grasped and the fingers are touched.

4. The Virtual Casualty Models

BioSimMER incorporates multiple injury types: tension pneumothorax, two types of head injury, severe exposure to Staphylococcal Enterotoxin B (SEB) and the symptoms presented by a "psychological case" – an uninjured person in shock. These injuries are representative of the combined injuries anticipated in BW scenarios, such as the one implemented for BioSimMER. The BioSimMER system incorporates dynamic casualty models that manifest the symptoms of these injuries. If the medic/trainee does not properly assess and treat these injuries, then the casualty may die. Figure 3 shows a virtual casualty with a head wound.

FIGURE 3
Virtual Casualty with Head Trauma

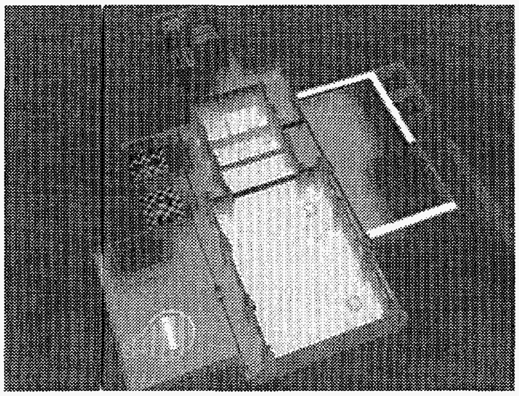


The underlying medical models for the injuries were created using the ExGen software and were developed by the Tekamah Corporation[12]. ExGen utilizes a Finite State Automata (FSA) to model the dynamic state of the casualty, the degradation of that state over time, and the changes brought about by the actions of the trainee. The BioSimMER trainer presents this state to the user via the virtual casualty, who might, for example, present abnormal vitals, skin color changes, be unable to respond to stimuli, or lose consciousness. BioSimMER interprets and "creates" the actions that the user performs (for example, checking for pupilary response with a penlight) as described in Section C.2 above. It then sends this information to the ExGen FSA, which determines the appropriate state changes for the casualty and transmits this back to BioSimMER. These state changes are then created in the virtual world of the trainee (e.g. the pupils dilate or they don't), who must respond appropriately.

5. Agent Transport Model

The transportation and disposition of the SEB agent through the virtual airport was realistically modeled using the CONTAIN software developed at Sandia National Laboratories. CONTAIN was originally developed to model the interior transport of nuclear radiation through a facility in the event of an accident[6]. It has since been extended to permit modeling of the transport of chemical and biological agents within a facility[1]. Figure 4 shows a point-in-time snapshot of the visualization of SEB transport through the airport. Utilizing the CONTAIN calculations, BioSimMER is able to accurately simulate the dosage of SEB for casualties within the facility for use in injury modeling. It also permits BioSimMER to realistically model the readings for simulated sensors placed within the facility. Placement of sensors and detectors is another task that first responders will be called upon to perform in the event of a BW incident.

FIGURE 4
Visualization of SEB Transport Through the Airport



D. DISCUSSION AND FUTURE WORK

This paper has presented a prototype VR-based trainer for first responders. The initial scenario combines conventional injuries with the effects of SEB exposure brought about by a terrorist act. The BioSimMER system has been demonstrated and will be fielded at the National Emergency Response and Rescue Training Center at Texas A&M University in FY99. This will permit initial evaluation of the system by potential end-users. The goal is to carry out human performance studies to determine the effectiveness of BioSimMER as a training tool.

It is also anticipated that in FY99, the BioSimMER scenarios will be extended to include rescue within a collapsed structure. This will require the addition of crush injury models and the extension of the BioSimMER VR interface to incorporate two new capabilities: presentation of the visual scene rendered to model infrared night vision goggles, and the integration of multiple point tactile feedback as a way of representing the confining spaces of a collapsed structure.

ACKNOWLEDGEMENTS

The work described in this paper was a team effort. We would like to thank the following researchers for their vital contributions to this project: From Tekamah Corporation , Eric Allely and Scott Thompson, who developed the injury models. From Sandia National Laboratories, Monica Prasad, who developed the graphical models; James Singer, who developed the sound server and animation software; Lydia Tapia who developed the voice recognition and casualty animations; Ken Murata and John Brockman, who developed the agent transport model. We would also like to thank Rick Satava, Bill Pugh, and John Silva for their support of this and previous work.

This work was sponsored by the Defense Advanced Research Projects Agency (DARPA). Previous work upon which it is built was sponsored by DARPA and the Naval Health Research Center. The work was performed at Sandia National Laboratories, which is managed by Lockheed-Martin for the U.S. Department of Energy under Contract DE-AC04-94AL86000.

REFERENCES

1. "Application of CONTAIN Analysis Code to the Transport of SEB," Brockman, J. and Murata, K., *Internal Project Review,* Sandia National Laboratories, Albuquerque, NM, 1998.

2. "Surgical Simulation: An Emerging Technology for Training in Emergency Medicine," Delp, S., Loan, P., Basdogan, C., and Rosen, J., *Presence: Teleoperators and Virtual Environments*, Vol. 6, No. 2, 1997.

3. *First Responder Chem-Bio Handbook. A Practical Manual for First Responders,* FR-CBH, Tempest Publishing, Alexandria VA, 1998.

4. "Techniques for Active Embodiment of Participants in Virtual Environments," R. Hightower and S. Stansfield, *Proceedings of the 1996 IMAGE Conference*, Scottsdale, AZ, 23-28 June 1996.

5. "Building a Virtual Reality Temporal Bone Dissection Simulator," Kuppersmith, R., Johnston, R., Moreau, D., Loftin, R., and Jenkins, H., *Medicine Meets Virtual Reality*, K.S. Morgan, H.M. Hoffman, D. Stredney, and S.J. Weghorst (eds.), IOSPress, Amsterdam, 1997.

6. *Code Manual for CONTAIN 2.0: A Computer Code for Nuclear Reactor Containment Analysis*, Murata, K., et al., *Technical Report SAND97-1735*, Sandia National Laboratories, Albuquerque, NM, 1997 .

7. "Virtual Endoscopy: Evaluation Using the Visible Human Datasets and Comparison with Real Endoscopy in Patients," Robb, R., *Medicine Meets Virtual Reality*, K.S. Morgan, H.M. Hoffman, D. Stredney, and S.J. Weghorst (eds.), IOS Press, Amsterdam, 1997.

8. "Virtual Environments for Medical Training and Education," Satava, R. and Jones, S., *Presence: Teleoperators and Virtual Environments*, Vol. 6, No. 2, 1997.

9. "Virtual Actors and Avatars in a Flexible, User-Determined-Scenario Environment," Shawver, D., *Proceedings of the Virtual Reality Annual International Symposium*, Albuquerque, NM, 1-6 March 1996

10. "An Application of Shared Virtual Reality to Situational Training," Stansfield, S., Miner, N., Shawver, D. and Rogers, D., *Proceedings of the Virtual Reality Annual International Symposium*, Triangle Research Park, NC., March, 1996.

11. "MediSim: A Prototype VR System for Training Medical First Responders," Stansfield, S., Shawver, D., and Sobel, A., *Proceedings of the Virtual Reality Annual International Symposium,* Atlanta, GA, March, 1998.

12. "Finite State Automata as a Model for Casualty Simulation," Thompson, S. and Allely, E., *Technical Report,* Tekamah Corporation, Rockville, MD, 1997.