Emergency Medicine Training with Gesture Driven Interactive 3D Simulations

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ABSTRACT

In this paper we present the prototype system that will be used in the RIMSI project for the simulation and training of medical and para-medical personnel in emergency medicine. The use of immersive simulations in medical training is extremely useful to confront emergency operators with scenarios that range from usual (e.g. unconscious person on the ground) to extreme (car accident with several injured people) without posing the simulation participants in any harm. It is critical to exploit 3D virtual worlds in order to provide as much contextual information as possible to the operators. In fact each emergency procedure needs to be adapted depending on the environmental threats and the presence of multiple injured people in need of assistance or bystanders. The presented prototype will simulate virtual first aid scenarios with interactive 3D graphics. Users will interact with a gesture based interface based on Kinect^{TM}. The interface will improve the immersive capability of the system and provide a natural interface for navigation and interaction with the virtual environment.

Categories and Subject Descriptors

H.4 [**Computer Applications**]: Life and Medical Sciences—*Health*

Keywords

Simulation, Natural Interaction, Medical Training

1. INTRODUCTION

In the field of emergency medicine simulation is extremely useful to teach Emergency Medical Technicians (EMTs) and medics to operate in harmful or critical situations. Medical simulations have been enacted for centuries even if in primitive forms [11]. Practice is a key component for the maintenance and learning of skills in medicine [6] and in this regard medical simulation encompasses different solutions. According to David Gaba there are five categories of medical simulation: verbal simulations, standardized patients, part-task trainers, electronic patients and computer patients. A verbal simulation is a role playing game. Standardized patients are actors employed to train junior doctors in communication and physical examination skills as well as patient history taking. Task trainers usually depict body parts and the most complex version are also used as surgical trainers. Electronic patients are probably the most realistic devices for simulations. They are full size and weight mannequins with human like behavior (eye blinking, breathe and pulse) and are usually computer controlled in order to induce disease symptoms. Electronic patients and task trainers are the most expensive devices but with respect to standardized patients and verbal simulations ease the repeatability of the simulation scenarios. To reduce the cost of simulations computer patients can be used. Computer patients are software based interactive characters that have the same purpose of standardized patients but can also in part replace electronic patients.

The interesting feature of computer based medical simulation is the possibility to replicate very complex scenarios at a very low cost. As an example imagine the scenario of a bus crash on a highway. Such a scenario requires the intervention of multiple medical operators with the need of a high skill in managing and prioritizing patient assistance procedures. The enactment of such a scenario requires a vast amount of free ground, several electronic patients and actors together with trainees. Electronic mannequins are quite expensive since their cost ranges from 20k to 80k \$. Only a few medical schools and the military can afford such expenses. Therefore simulations involving the use of an electronic mannequin are usually enacted in ER-like environment or in simple non-hospital environment and they use a single electronic patient.

A computer based simulation can also improve the trainee environmental awareness without any risk for the simulation participants and medical operators can be confronted with situations involving many risks both for the patient and themselves. These situations can be simulated realistically at no cost and without any risk for the trainees. An example is a BLSD scenario in an apartment of a burning building where simulation participants need to take care of their team safety before assisting the patient requesting, if needed, firemen support.

Computer medical training simulation have covered vari-

UXeLATE'12, November 2, 2012, Nara, Japan.

ous needs in the past. Laerdal MicroSim [1] is a non immersive simulation that presents to trainees pre-hospital, in-hospital and military scenarios. Laerdal actually commercialize three separate versions. As can be seen in Figure 1 the user can interact with the patient with a simple 2D interface and has a static view of the scene. A more immersive simulation has been built by Sliney et al. [13]. Their system, named JDoc, simulate an hospital and has the purpose to train junior doctors to deal with the stress of a hectic hospital. Their system has therefore a double function, on the one hand it provides a realistic simulation of an environment with which doctors need to familiarize, on the other hand it offers simulations of patient cases which are also reconfigurable by senior doctors and teachers.

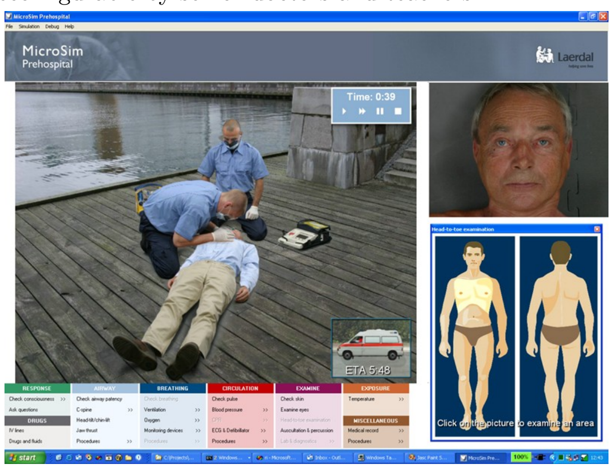

Figure 1: Laerdal MicroSim pre-hospital scenario.

In this paper we present EMERGENZA (emergency in Italian), the prototype system that will be used in the RIMSI[1] project for the simulation and training of medical and paramedical personnel in emergency medicine. Our prototype aims at reproducing pre-hospital scenarios with critical environmental situations in a reconfigurable way. We decided to portrait this kind of scenarios since they are the most expensive and difficult to reproduce in simulation facilities. The system will be composed by a scenario editor for the instructors and a simulator. Users will be able to navigate a virtual realistic environment as both first and third person character controllers. To improve the immersivity of the system a gesture driven interface based on the Kinect™sensor will be developed.

2. USE CASES AND SCENARIOS

In medical simulation one can aim at training communication between members of a team, situational awareness or personal skills. The latter require precise measurement or human evaluation of procedures. In these drills a few millimeters of error may result in a critical outcome for the patient. Furthermore it is really difficult to obtain an effective virtual simulation for personal skill training, while, for the former, there is the need of generating a sufficient complexity in the scenario. For example, while assisting a pediatric patient, parents may interfere in the procedure, but at the same time they are probably the only and most accurate source of information on the patient history and the cause for his disease. To improve medical operators communication skills it is also important to be able to repeat simulations. Simulation may be repeated with the same parameters or with slight variations. This kind of simulation is usually performed with the use of expensive electronic patients or mannequins that are remotely controlled by instructors.

Unless the use of a virtual environment may decrease the realism of the simulation, since it would be complicated to deliver the tactile information that a physical mannequin can, anyway it offers substantial advantages: it both allows to decrease the cost of the simulation and to increase the simulation complexity. A first point is to vary the environmental conditions so to force environmental awareness in the trainees. A second point is to increase the amount of patients in need of assistance with no cost at all. Moreover the use of non-playing characters (NPC), in any number, can greatly improve the communication complexity and realism of the simulation.

According to these needs the EMERGENZA game will be composed of a simulator and a scenario editor that will allow instructors to mix different source of complexity in the emergency procedure scenario. First it will be possible to place the patient in different positions in the environment, vary the environment itself (e.g. a house, a road, a factory) and to add to each scenario several additional threats for the safety of patients and medical operators. Second it will be possible to insert various patients conditions, like his pose and state of consciousness, and different responses to therapies that require consistent standardized procedures. A sample patient configuration is shown in Figure 6.

The virtual world is therefore reconfigurable and the same environment can generate several different situations. It will be possible to employ NPCs. NPCs can have different roles: they may be relatives, friends of the patient or simple bystanders, but they can also be members of the medical team performing the procedure. In both cases they are employed to deliver information to the player. As a special case a NPC can serve to augment the sensory input of the experience. As an example, although smell generators exist [2] and can be relatively affordable, an NPC can be exploited to provide information on the environment such claiming she is smelling smoke or other odors that may indicate danger.

Particularly we present a possible scenario that EMERGENZA can simulate: basic life support and defibrillation (BLSD) procedure in a house with a gas leak. In this scenario a player (the doctor) and a NPC (the assistant) will be used. Two of the available models are shown in Figure 2.

The flow diagram in Figures 3 and 4 is the complete event tree of the scenario. Note how the NPC is used to deliver information or to deliver warnings if the player is not performing a procedure correctly.

This scenario depicts a typical BLSD procedure with the added risk of a gas leak. The gas smell and the possible leak is signaled by the assistant. The player has to decide how to confront this situation, he could ask for help, leave the house or locate the gas source. The player can navigate in the virtual rooms to check the environment safety. If the player decide to locate the gas source and block the leak then he can proceed to the BLSD. An animation of the player removing the source of danger, in this case the gas leak, is used to signal that the procedure can start safely, as

[1] http://www.micc.unifi.it/rimsi

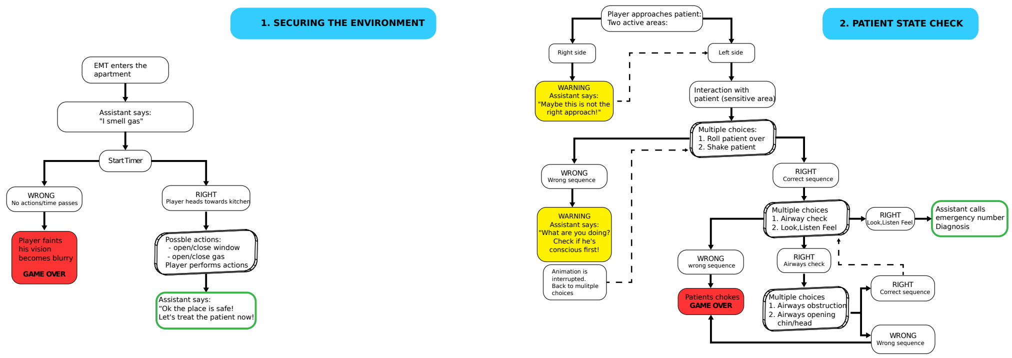

Figure 3: Flow diagram of the first part of the BLSD scenario.

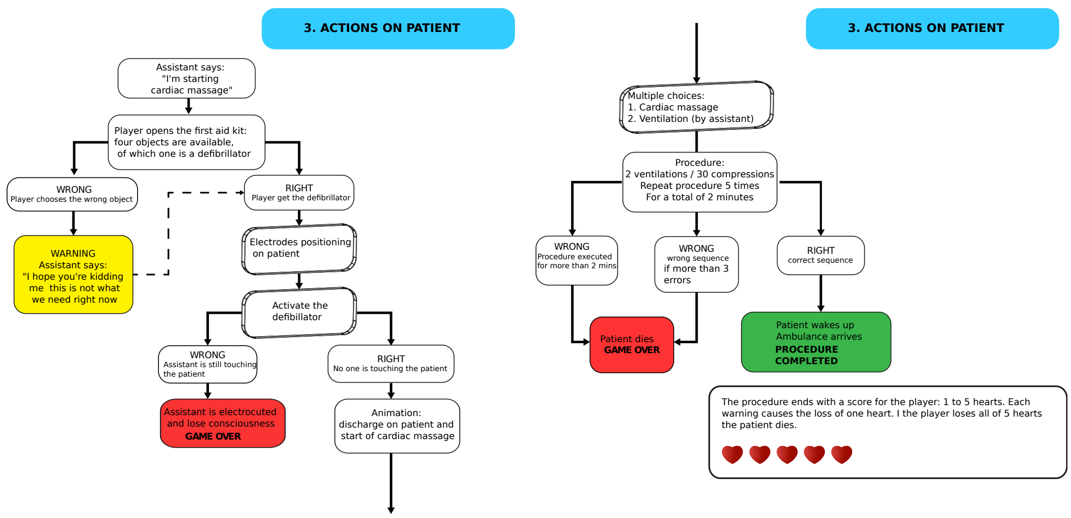

Figure 4: Flow diagram of the second part of BLSD scenario.

Figure 2: Two of the available characters a doctor and his assistant. The doctor will be mainly used as a playing character while the assistant as a NPC.

shown in Figure 5. The BLSD procedure as can be seen in Figure 4 involves the use of objects such as the defibrillator, the Ambu balloon or simply the phone to call for further help. Moreover in order to correctly perform the procedure there is need to interact with these objects, their joint use, the environment and the patient.

Figure 5: Animation of player securing the environment before patient assistance.

The BLSD procedure as can be seen in Figure 4 involve the use of objects such as the defibrillator, the Ambu balloon or simply the phone to call for further help. Moreover to

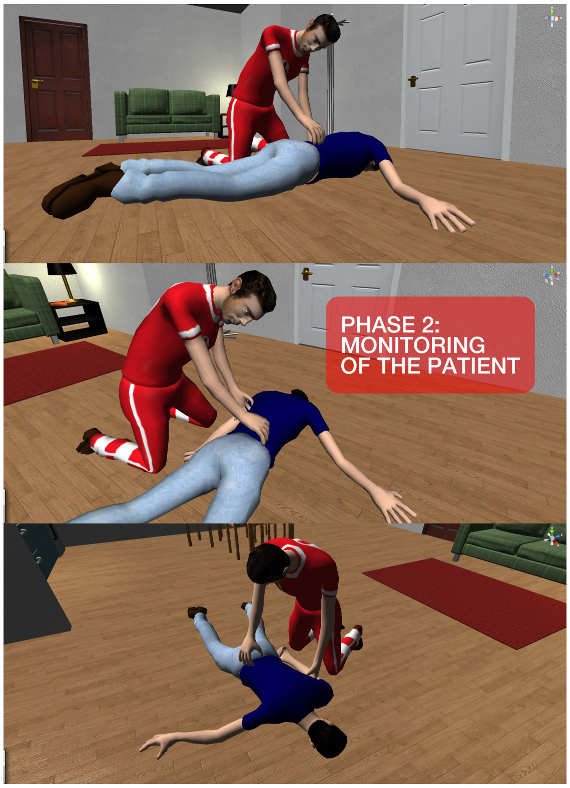

Figure 6: Animation of player securing the environment before patient assistance.

correctly perform the procedure there is need to interact with these objects and the joint use of these objects and the environment or patient.

3. NAVIGATION AND INTERACTION

The proposed system will be a free-roam game. A free-roam game is a game where there is no predefined order in which actions need to be taken in order to obtain accomplishments. This is obviously a mean of improving realism since as in real life a user may decide to assist a patient before another or patrol the environment to assess its safety before beginning the assistance of patients. Although some actions need to be taken in order, as an example if multiple patients are present in the scene the more severely injured should be assisted first, a wrong decision in this case may not necessarily lead to a patient death. Timers will be used in order to assess the player performance and to indicate the need of different procedures.

The environment will be designed with realistic features, for example a house will have furniture, lights and house appliance. Some sample screenshots of this environment are shown in Figure 7.

The navigation in the virtual world is made possible by both a standard keyboard+mouse interface and a gesture driven Kinect^{TM}interface. In the case of the keyboard+mouse input 3D menus will appear to allow the player to chose between different actions. In the case of the gesture driven interface the navigation is performed by the variation of user posture. A pointing gesture can be used to move forward in a certain direction, while the orientation of the head can be used to vary the camera orientation in both first and third person modalities. Moreover the user posture can alter the camera position, for example the action of bending causes the camera to lower with respect to the ground plane.

Figure 7: A sample scene from the simulation prototype.

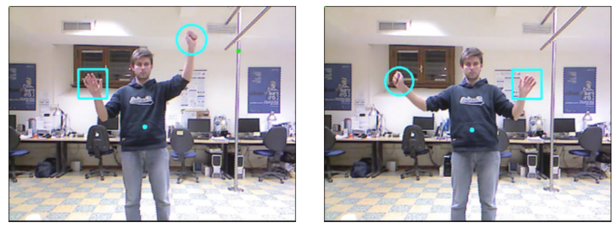

Figure 8: Hand status detection: square (open hand), circle (closed hand).

Simple or complex gestures can be recognized automatically [8, 10] with the use of a depth camera and a skeletal tracking system[12]. The only limitation of the standard Kinect^{TM}SDK is the lack of a hand pose recognition algorithm. The recognition of the hand pose allows a system to recognize on/off actions such as activating, grabbing or manipulating an object in the 3D world. This limitation is often handled with the use of persistence, i.e. a user must keep her arm still for a not so short amount of time (3 seconds) while aiming at some sensitive area in order to interact with it.

We propose to employ an improvement to this system based on a robust hand pose classifier we developed [4]. The proposed system is trained on a large dataset (30k+) of hands in closed and open status recorded at several distances, from eight subjects of different genders wearing various clothings. This vision module improves the responsiveness of the interface and, detecting the state of the hands of all players, enables the activation and manipulation of 3D objects. See Figure 8 for an example of the detector output.

As an example, in the reanimation scenario, the player could grab the electrodes one at a time or with both hands by simply pointing at them and closing the hand(s) and place them on the patient body by opening his hand(s).

The vision module represents a hand, segmented with a skeletal tracker, with a regular grid of 5 SURF[5] descriptors. This feature is fed to a nonlinear SVM classifier that predicts the state of the hand. This module has a very low overhead in terms of computation, in fact as can be seen in Figure 9 a detection can be obtained in less than a frame, although this detection can be noisy. This module has an additional parameter that improve the robustness. The classifier is cascaded with a temporal Kalman filter that outputs a smooth estimate of the hand state. The σ parameter can be varied obtaining a trade-off between responsiveness and robustness of the system.

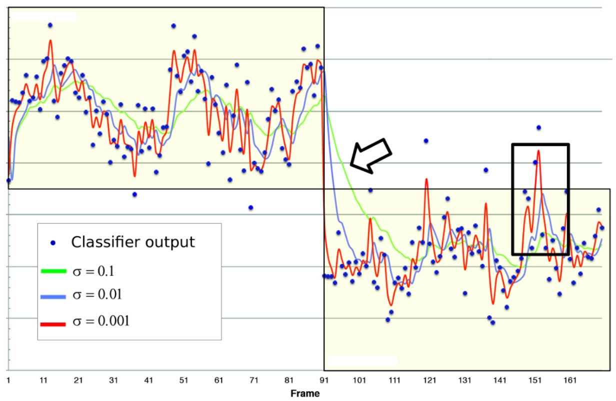

Figure 9: Filtered and unfiltered detections with different Kalman filter measurement errors.

Overall the hand status recognition module has an extremely high reliability with an accuracy of to 98.95%. The temporal smoothing improve the result by 2%. As seen in Figure 9 with a less responsive system it is possible to raise the accuracy further.

The game is based on the Unity3D [3] game engine and it runs on any recent hardware (not older than 4 years). Scenes and models have been realized with Maya. The Kinect^{TM}interface is not mandatory in order to ease the system deployment and diffusion.

4. EVALUATION OF USER OPERATIONS

Game dynamics can define the effectiveness of the operations. Player performance is assessed through game dynamics but also in a debriefing stage with instructors. During gameplay the player is given continuous feedback from the system on the effectiveness of his actions. Even a successful game need to be debriefed to understand if the communication and the evaluation of environment and patient have been performed in a safe and correct way.

The use of a completely virtual simulation allows to produce digital logs of all the events happened during the acted procedure. This game logs not only contain patient vital signs and symptoms but also the exact position (actually if the Kinect^{TM}interface is used even the posture) of all players. With this data it is possible to literally playback the whole simulation, switching the point of view and analyzing in detail the behavior of all the participants. Debriefing in simulation is as important as the simulation itself [7] and the proposed system not only allows the simulation of otherwise too expensive or too dangerous situations but greatly improves this phase of the training.

5. CONCLUSION

Simulation in medicine has really improved in both fidelity and validity, but still there are several issues that justify skepticism in his adoption in the training process. Nonetheless several schools of medicine all around the world are integrating simulations in doctor training and even offer certifications for simulation centers[9]. The main reason of delay in the adoption are cost of personnel, equipment and programs that can be mitigated with the creation of large structures that promote the collaboration between different hospital units.

In this context our proposed prototype is extremely valuable. In fact we are reducing the cost of simulation replacing expensive structures and devices with virtual worlds. Moreover we are proposing a system that enable the simulation of dangerous and extreme scenarios enriching the training of junior doctors.

The use of the scenario creator enable trainers to define complex and varied situations to keep their trainees always focused on the environment, patient condition and bystanders. The whole standard procedure can thus be learned as a complex interaction of medics, bystanders and patients in the environment.

In our opinion the debriefing stage is also improved with the use of a "recording" of the simulation session. This recording allows to playback all the phases of the simulation and even play again the very same sequence of events from a point that determined a failure.

6. ACKNOWLEDGMENTS

This work was supported in part by the Regione Toscana RIMSI Project (Program POR CREO FESR 2007-2013).

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