Collaborative Virtual Environments as Research and Teaching Instruments in the Field of Disaster Medicine: the “e-DISTRICT CiPro” Simulator

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Abstract
The virtual reality simulator used in the e-DISTRICT CiPro Pilot-Project, in the context of the EU programme Leonardo da Vinci II, allows the realization of an Internet based Collaborative Virtual Environment and it can be used for Education and Training for Civil Protection Operators, and for Research purposes in new operational protocols and their effectiveness (which would be very expensive in case of real drills, and also very difficult to organize). In this article we focus on the goals of the e-District CiPro Project, and we present the virtual reality simulator. We also address the importance of the detail level of the scenarios and we consider their customization and their integration with other software that simulates the phase of treatment in hospital.

Keywords--- Disaster Medicine, Emergency Medicine, Internet, Virtual Reality, Computer Game Learning, Multi-user Computer Games, Collaborative Virtual Environments, Europe

1 Introduction

Emergency medicine deals with the stabilization and the treatment of patients who suffer from pathologies that evolve very rapidly and that carry a high mortality risk if no effective measures are taken within a short time. In such a situation there is an ideal balance between resources and needs. Another branch of Medical Sciences, Disaster Medicine, has to face complex situations where there is a strong imbalance between needs and available resources. Within the Pilot Project “European DIStance TRaining Interactive and Collaborative Tools for the Civil Protection” (e-DISTRICT CiPro – www.edcipro.org) developed in the framework of the EU programme “Leonardo da Vinci II” through the collaboration of 11 partners of 6 different European countries (Italy, Belgium, Ireland, Romania, Spain, Hungary), we have implemented a prototype of distance-learning system. It is based on some learning modules in SCORM format (an international standard for e-learning modules) and a 3D multi-user Common Virtual Environment. The latter allows the training of all the actors taking part to Rescue Operation in case of Mass Casualty Incident (MCI) or Disaster, such as Medical Doctors, Nurses, Fire Brigades, Civil Protection, etc. The prototype is an Internet based integrated system for distance learning that contains a competence evaluation system (which allows to develop individually-tailored learning programmes), Educational Learning Modules, and – as said above - a 3D Collaborative Virtual Environment. This paper will focus on this last topic. One of the first tasks carried out by the Project Partners was the analysis of the competencies and expectations of the final users by a survey at European level. As far as the competencies are concerned we had three main groups: a) personnel related to the Medical Area: 42.4%; b) personnel related to the Civil Protection Area: 64.4%; c) personnel involved in Big Sport Events: 18.6% (out of 61 properly filled questionnaires). As far as the Medical Area is concerned, we had 15 vocational training categories the European Institutions and Hospitals promoted in the previous two years, ranging from the management of the pre-hospital phase to the
hospital phase, Logistics, Planning, Toxicology, Mental Health, etc. It was possible to find out that 39% of people had Coordination and Communication attitude; 39% had Planning attitude; 37.3% wanted to be involved in Disaster Risk Analysis (source: e-DISTRICT CiPro Report 1, 2005 [1]). Those data suggest that not only a Training tool but also a complete framework for Education purposes was needed.

The paper is organized as follows: in Sec. 2 the simulation scenario is outlined, in Sec. 3 the innovative (from the application point of view) and technological aspects of the simulator are presented, Sec. 4 issues the level of realism actually needed in the considered application field, and finally we summarize the results achieved and the future developments in Sec. 5.

2 Simulation Scenario

The 3D scenario developed within e-DISTRICT CiPro is a stadium with 23,800 spectators (Figure 1 (d)). Following an accident in a nearby chemical plant, the Stadium must be evacuated. The increasing panic and further accidents happening in the Stadium (the north-west tier falls down after an explosion due to a local fire) require that all the emergency squads (Firemen, Medical Doctors, Nurses, Civil Protection, Volunteers) co-operate to face the situation. The nearby Hospitals will be responsible for organizing spaces and for trying to guarantee the highest possible receptivity, even if neither the number nor the type of the injured people involved are known in advance. The road connecting the accident scenario and the hospitals will probably be congested by traffic and it will not be easy to make an estimation of the time taken to drive from one location to another. The current version of the 3D Simulator just includes the pre-Hospital phase. However it is possible to imagine an interconnection with an in-Hospital phase Simulators such as HDPnetS® (Hospital Disaster Preparedness Networked Simulator, developed by Virtual Engine S.r.l., www.virtualengine.it) that is specific for these purpose (see Section 4).

The key elements in the representation of this situation are: structural damages of the north-west tribune; flames; fire extinguishers; smoke that impairs the vision of the Rescue Personnel; people trapped under the rubble; “walking woundeds”; possibility of building an Advanced Medical Post (AMP), which the Incident Commander can establish in the position that he evaluates as the most appropriate: this is a very important element, because if the decision of setting up an AMP is made, its location will be crucial for the logistics aspects and for the global outcome.

The game develops according to the following steps:

- The Fire Brigades use fire extinguishers, protective barriers and extricate injured people; in addition to this they have to refer (via a chat system simulating a multichannel radio) to the Commander of the Fire Brigades about the number of victims. Finally they will declare— if this is possible—a whole area or part of the area to be safe so that the medical Rescue Teams may bring help;
- The Medical Personnel is divided into three squads: one has to do the Triage and another has to take care of the Victims. The other group of doctors are in charge as Command team and of the AMP tent: the latter have to guarantee the normal in-out flow of the patients treated on the spot. In Figure 1 some visualization examples are shown. In particular in (a) we can see that the AMP is located in the middle of the field, a choice which from the logistic point of view will turn out to be wrong, in (b) a view from the tiers is shown, and in (c) the rubble after the collapsing of the north-west tribune is shown, with smoke that makes the evaluation of the scene difficult.
  
For each patient, his/her status (e.g. the Vital Signs) can be visualized and actions can be taken, depending on the specific role of a rescuer. In particular rescuers can:
- evaluate the state of consciousness through the Glasgow Coma Score (GCS), in its Eye, Verbal and Motor components; evaluate the symmetry of the chest movement; evaluate the pupillary diameter and the reactivity; evaluate the burned body surface (in realisation); evaluate if the patient is immobile, moving, sitting, walking.
- This visual information (and, in the case of the V component of the GSC, also the audio information) allows: to carry out the triage (for example following the START protocol); to detect tension pneumothorax; to diagnose cerebral damage following an head trauma; the assumption of severe intoxication from smoke inhalation; the evaluation of possible damages to the spine. The detail level needed to convey these audio/visual information is higher than that provided by the 3D VR simulation engine employed: for this reason once a user is working on a specific patient, a more refined audio visual representation is presented in a separate pop-up window (see Figure 4 and Figure 6 (a)).

3 Innovative and technological aspects

In this section we briefly describe the innovation that the e-DISTRICT CiPro Virtual Reality simulator brings in
the field of disaster medicine teaching and outline the technological choices made for the implementation of the prototype.

3.1 Multi-user 3D simulation on the Internet

The target users of the prototype 3D Virtual Reality simulator built in the project are Civil Protection operators, located in different European Countries. It was required to build an environment that could be used through the Internet and that could be deployed and developed at low cost.

The main functions required were: the possibility of forming help squads (possibly constituted by a large number of helpers); the possibility of creating communication channels among the squads; the possibility of recruiting a huge number of players (thanks to the accessibility of the simulator from a simple PC).

Many existing Game and Virtual Reality engines were considered and evaluated before starting the development of the simulator: Torque game engine (www.garagegames.com), Unreal (www.unrealtechnology.com), Blaxxun (www.blaxxun.com, Windows only at the moment) just to cite some. The key issue in the choice was not obtain the state-of-the-art visual realism, but to reduce both the production and the development cost. This led to the choice of using VRML based graphic and Blaxxun technology. The effectiveness of the chosen level of visual representation will be considered in Section 4.

3.2 Representation of the key elements

In designing the 3D environment and the “role game” interface, efforts have been taken to obtain a “realistic enough” representation of both the scenario and the patients.

The key elements for the scenario representation are: infrastructures, damage to the infrastructures with related accessibility issues, environmental elements that make understanding of what is happening in the scenario more or less difficult (e.g. smoke, rubble, fire and structural collapse may impair the vision).

The key elements for the patients representation, which distinguishes our prototype from commercial patients simulators, is the actual visualisation of clinical signs rather than a representation through numbers. In many “patient simulators”, the evaluation of the respiration frequency – as required in the START Triage protocol – is performed by literally observing the inspiration and expiration movement, as it is in the reality, rather than looking at numbers on the screen as in commercial simulators.

Thanks to the above mentioned points the simulator produces results that are particularly effective in satisfying the following needs: training of people involved in rescue operations both on the national and the international level; possibility of moving within a virtual world represented through 3D graphics where each player can meet the other players, who are represented by the respective avatars, or interactive objects on which it is possible to intervene; evaluation of the environmental safety; patients management (triage, extrication of people from rubble, application of therapy procedures, management of the AMP and of the collecting areas, transfer to the destination hospitals); availability of a medical-logistical research instrument that aids understanding the ability of the operators to face the difficulties in a situation in which normal training and communication cannot be used; performance evaluation, made on the basis of a detailed report of the activities carried out by all the participants in each individual moment of the action.

In our vision, the e-DISTRICT CiPro simulator is an instrument for the operator’s cultural education and training. While training addresses the learning of a well-known protocol or decisional pattern in highly branched decisional trees (in some extent this is the case of Emergency Medicine procedures), Education deals with
Problem Solving issues, in situations that constantly change and that cannot be identified in advance (as, in some extent, in Disaster Medicine). It also supplies the decision makers with methods to find the best possible solution, and not with the solution itself. Embedded in the 3D Simulator is the START Triage Protocol [2]; besides the protocol, every decision taken by the players will be based on “positive improvisation”. A classical example from the literature is the following: if the Triage tags get lost for any reasons, how will I perform the Triage procedures? [3] In the article “Nurses in war” (D’Antonio, 2002) the Author describes a way the Nurses could have performed the Triage procedures using their lipsticks during the Pearl Harbor attack in World War II. The Triage Tag issue is just one of the most simple possible occurring events. In the specific case of our 3D Simulator, we allow a certain degree of discretionality in doing or not doing some logistical procedures (some of them expected to be right), such as the set-up of the Advanced Medical Post tent, and its location. This decision could be crucial. Another unpredictable factor is how effectively the players (Fire Brigades, Medical Doctors, etc.) will interact and communicate with each other. A further non-predetermined thing concerns how the Command team will report on the situation to the representatives of the Local Government, how they take care of relations with the Press, how will they handle ways to quickly and effectively communicate with the Rescue teams on the spot. All these elements are very useful for the debriefing phase, in order to understand what the “right” or “wrong” decisions and procedures turned out to be interesting or impairing the Rescue chain.

The only training factor is just a part of the “skills” necessary to handle the Scene. In fact, if the collapsing of the tiers is not the first cause of the chain of the events but just one of the components, the ability to integrate and interpret the scenario as a whole becomes fundamental.

3.3 Technological choices

In order to realize a game situation and take part to the game itself two interfaces are necessary: one for the preparation of the drill, used by the teachers, and a second one for the running of the game, used by the group of the players/students. The teacher’s interface is used to update a data base that contains all the information relating to a specific drill. The interface which the student accesses after having authenticated himself and after having selected his own role is shown in Figure 2. This interface is also used by the teacher who has the master role during the game.

![Figure 2: The player interface](image1)

Figure 3 shows the general architecture of the system. It is a typical client-server architecture constituted by three main components: the student interface (player client), the teacher interface (drills designer client) and the game server.

![Figure 3: The multi-user simulator architecture](image2)

The functional mechanism integrates a VR 3D simulation engine and dynamical web pages. The system described up to now has been implemented through the following technologies: Blaxxun for the management of the 3D virtual environment [4] (many Universities used similar technologies for training purposes [5] but often without properly made Educational support, that in our project is given by SCORM compliant modules); Cult 3D (www.cult3d.com) for the more detailed 3D visualization used during patient treatment, the Apache Web server, PHP for the interaction with data bases, Javascript for the interaction with the user and the synchronization of the different frames, and finally the MySQL DBMS.
3.4 Creating new scenarios

The philosophy of the e-DISTRICT CiPro prototype is to allow the customisation of learning contents, which can be tailored for a specific organisation or government that would like to use the framework as a learning or research tool. Currently the customisation can be obtain by means of a simple web application that allows include new automata representing the possible evolution of each patient or controllable object (Figure 5), and to define the initial placement of the simulation objects in the 3D scenario. The graphical features (objects’ appearance and animations) can be chosen from a graphic models library. For the sake of space we do not discuss in this paper the 3D scenario and objects production problem. However this issue has been covered by the project with a considerable effort.

4 What is useful and what is less useful to represent in computer simulated 3D scenario

The anaesthesiologists-intensivists, and the emergency physicians tend to develop methods that allow them a quick visual interpretation of clinical signs, visual skills, multiparametric monitors, and environment evaluation. Very often the process of recognising the vital parameters profits from the ability of the operator to discern which information among the manifold of visual and sensorial information is useful for the interpretation of the given case [6].

In a recent work we compared the capability to understand some clinical signs by using two levels of photorealism within 3D computer simulations [7]. A more detailed photorealism level was offered by the Virtual Manikin used within e-DISTRICT CiPro while a less defined photorealism was supplied by the 3D City Car Accident prototype Simulator [8] (see Figure 6).

The results of the comparison suggest that the comprehension ability was very similar for both the group of individuals that had received an animation with less representation details and the group that had received the animation with more representation details.

As far as the Victims are concerned, the 3D Simulator allows several “layers” of data visualisation: a) the players see the Victims’ avatar (walking, sitting, laying or immobilised under the rubble); b) by clicking on the Avatar, a video showing the head, chest and arms of the Patient appears: these videos are produced using the Virtual Manikin (www.virtualmanikin.com ) realized by the Cult3D technology (www.cult3d.com ) used for the single-user exercitation: the Manikin speaks in order to allow the evaluation of the GCS – Verbal.

Besides the Vital Signs that the user has to evaluate just looking at the Manikin, other information are then shown as numeric data.

Other kind of visualisation include the so-called “non verbal communication”: we isolated four main useful gestures, such as a “finger pointing to something”, a “no way” gesture, a “yes” gesture and an “I’m here” gesture.

Visualisation made within a Virtual Collaborative Environment is useful to learn how to react to hostile conditions or environments and also to understand the interfacing problems with the other game figures (a trivial question: if the helpers, physicians and nurses, are dressed in the same way, how will it then be possible to understand who the doctor is? This is one of the problems...
of correctly reading the scenario, especially in the case of aid operations carried out in foreign countries). The limits of this kind of representation start to become visible when the main task is to manage sheer logistical aspects on a vast area, as may be the case in the metropolitan area of a big town, with its hospital and infrastructures. During the real scale drill performed within the VI version of the European Master in Disaster Medicine (www.dismedmaster.com), a II level Master Degree offered by the Università del Piemonte Orientale and the Vrije Universiteit Brussel in collaboration with world leading universities, the patients were played by medical students. These were able to learn how a patient suffering from a specific pathology really appears.

Nevertheless there was also the need to simulate the in-Hospital phase. The solution was found and it consisted in using a software programme for micro- and macro-simulation in the event of disaster, HDPnetS. The patients/students, after having been stabilized, were transported to a hangar that symbolized “all the wards/hospitals” [9]. Here a small intranet was installed where the HDPnetS software was running. Thank to this software it was possible to simulate the hospitalization of the patients and to control the state of the operating theatres and the state of the intensive therapies. In this way the general level of the simulation was very much improved. (see Figure 8 and Figure 9).

If the patients involved in a drill are volunteers who try to do their best to simulate the signs of some specific pathologies in their possible evolution, the e-DISTRICT CiPro patients are computerized algorithms that change state according to the treatment they receive, the time elapsed or according to the appropriateness of their transfer. Each state of each individual patient contains all the needed vital parameters and “gates” necessary to change to a less or more stable state.

A computer simulation that can satisfy both the aspects of a simulation taking place in and outside the hospital and the managing of an entire metropolitan area carried out by multiple users (macro-simulation) [10] with a strong logistical approach (“command-control” kind) could be carried out by allowing that the patients be sent out by the e-DISTRICT CiPro virtual simulator AMP and be assigned - through a virtual EMS – to the simulated hospitals. Both the e-DISTRICT CiPro and HDPnetS could share the same patient’s library since in both systems, in fact these are represented through similar finite state automata.

Finally an essential part of the system is the simulation log which can be used off-line to evaluate the performance of the students both for evaluation purposes.
and for a debriefing phase where the actions performed can be replayed and discussed in the “virtual classroom” so those students can learn from their errors. This is the part that most pertains to the cultural education rather than the pure training aspect.

5 Conclusions

A MEDLINE/PubMed search (official Medical Literature [11] ) with the keywords “Disaster Medicine” AND “Education” AND “Europe” only returns three articles written in the past four years world wide, while the fourth entry dates back to 1995. Disaster Medicine Education at University level is, in Europe, a matter still debated and no unified Academic rules seem to have been established about this Subject (de Boer, 1995 [12], Grunfeld, 1996 [15] ) . Some Authors (Cummings and Della Corte, 2006 [14] ) made a systematic review about Medical Education (under and post-graduate) in Disaster Medicine for physicians in the time-frame 1985-2006 and ranked as “good” 54 articles worldwide, 25 of them scored as “weak”, 25 as “moderate” and only four as “strong”, the latter being published after September 11, 2001. They conclude that the body of knowledge in official medical literature about this subject is limited before September 11, 2001 and improved since then. The main contribution of the e-DISTRICT CiPro is the aim of creating and promoting a framework for Education and Training in this field. As far as the 3D Simulator is concerned, it is one of the ‘bricks’ of this Project. In the next future we are planning to test in detail its effectiveness both from a usability point of view and from a properly Educational one. A usability issue already recognised is the non-effectiveness of textual chat communication (we are planning to use real walkie-talkie to allow a simpler and more natural way to speak). Further developments could include the creation of an exchange layer for the connection of the 3D Simulator to a in-Hospital simulator, and the improvement of the immersivity, for example, using one or more interconnected CAVEs [15]). It could also be useful to study the determinants of realism when planning a real-size drill.

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7 References

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