EMERGENCY MANAGEMENT TRAINING: USING A VIRTUAL REALITY REPRESENTATION OF THE DISASTER SITE TO TRAIN SITE DECISION MAKERS

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ABSTRACT

The application described in this paper is partly a stand-alone application and partly one of the modules of the MUSTER system (Multi-User System for Training Emergency Response). The system architecture and its modules are described in accompanying papers published in the TIEMEC '95 Proceedings (V. Andersen & HB Andersen, 1995, contains and overview of the MUSTER system, while details about specific modules, configurations and aspects of target scenarios are described in Balducelli et al., 1995, and in HB Andersen et al. 1995). In the paper we discuss some of the reasons why visual input is of particular importance to trainees who play the role of site decision makers.

Introduction

The visual features of a training environment may in some cases be crucial to the success of training whereas they will play a negligible role in others. For instance, when a pilot is trained in a full flight simulator which incorporates a state-of-the-art visual system, the training providers have spent several million dollars on just the visual system alone. They have done so, of course, precisely because there is reason to believe that pilots would not acquire - at least not nearly as efficiently, safely or as comprehensively as they do - the type of flight skills and knowledge they need if they are trained in simulators having more primitive visual systems. In contrast, when pilots learn pre-start check procedures, they need no visual system representing the world outside the cockpit. Consequently, to save costly lessons in the expensive full flight simulators such procedures training is often carried out in simulators which, developed at much more modest costs, have no visual (or motion) system.

Similar remarks could be made for a range of other domains involving real time control of safety critical systems or processes. Thus, for instance, anaesthetists are, in certain hospitals, trained to cope with rare but serious incidents by being exposed to two kinds of training environments (along with their on-the-job training in operating theatres during real anaesthesias provided by instructor-doctors). One kind of training environment involves a full-scale anaesthesia trainer comprising a mannequin (the 'patient') and all the usual anaesthesia equipment and instruments linked up with a simulation of the reactions of the anaesthetised 'patient'. (Gaba and DeAnda, 1988; Jensen *et al.* 1993). Another training environment is provided in a reduced and much less costly form by a stand-alone PC-based simulator. The latter, which runs underlying simulations which are similar to those of the full-scale simulator, provides feedback to the trainee only via a single computer screen and possibly auditory alarms (Schwid 1997). Now, the small-scale, PC-based simulator is a useful training system and it is, compared with the full-scale simulator, a quite sufficient training system for certain training purposes, namely the training of procedures and sequential condition-action steps. Where it is lacking is in providing trainees with clinical cues from the patient/mannequin and the various types of anaesthesia equipment and, very importantly, social interaction cues. So, the full-scale simulator is needed for training anaesthetists in developing good co-ordination skills and, in general, skills in handling incidents as a team. (Gaba *et al.* 1994; Jensen *et al.* 1993). In general, therefore, when designing training simulation environments the designers involved need to consider that certain tasks or job roles require, and certain others do not, that the operators and decision makers involved receive a relatively rich and dynamically updated visual feedback from the domain of operation.

Visual representation of site scenery in emergency management training

When considering the needs for training support for emergency management tasks, there is a distinction to be made in terms of the visual feedback required. Thus, without going into detail in analysing in general terms the differences between the tasks for which rich, dynamic feedback is necessary and those for which it is not, let us just note that there is an obvious distinction to be made between 'site' trainees and 'off-site' trainees. Thus, the requirements to visual representation are very different for these two types of trainees: there are on the one hand, trainees who, during real emergencies, will have available and who will exploit their view of the *site of emergency* and, on the other, trainees, usually placed in remote control centres, who will not have any such possibilities. It should be noted, however, that for the latter category, it will may well be the case that updated visual input will play a essential role for their ability to fulfil their tasks. Consider, for instance, emergencies involving - as in the case of the target applications of the MUSTER system - responses by personnel at remote centres controlling train traffic or harbour traffic. Among the staff of control centres, typically located some distance away from the site of the emergency, are people who rely essentially on control systems that provide graphic or character-based information and overviews, say, a display of the location and movements of trains. Hence, in order to provide a training environment with a suitable degree of realism, such trainees need to have some kind of simulated overview of the virtual trains in the virtual scenario.

However, it is in general more difficult to satisfy, in regard of visual representations of the virtual events taking place in the training scenario, the needs of *site trainees* than the needs *off-site trainees*. The site trainees in the MUSTER applications are decision makers involved in deploying, say, fire fighting units and ambulance crews. For the railway accident scenario that has been chosen as the MUSTER demonstration case a goods train carrying dangerous cargo has been derailed and several wagons have been overturned. At the same time, the surrounding terrain contains neighbouring tracks and steep slopes and brushes. It will be difficult to provide the chief decision makers, the Fire Brigade Chief and the Railway Emergency Manager, the Police and Ambulance Site Chiefs, with the right amount of information. Giving them a map, perhaps a dynamically updated map as contained in a GIS system, will tell them too much and too little. Too much because objects which would be occluded at certain angles of sight will be visible on a GIS or map representation; and too little because it is difficult to indicate on a map, without revealing the desired solutions, the suitable routes of approach, etc.

At the early stages of the MUSTER system design it was recognised among the project partners that some form of dynamic visual feedback had to be provided to field trainees; but no firm decision was made as to the way to provide such a feedback. Several ideas were discussed, including setting up a 'Lego'-table in the training supervisor's room and letting trainees have a video-view by way of pen-sized cameras from the Lego-world. According to this concept, the location of the virtual objects - which would be represented by toy train wagons, trees, tracks etc. would be recorded in a database and the movements of movable objects (resources) would be changed according to trainees' instructions. As an alternative it was discussed to have the movable objects on such a 'Lego' table (fire units, wounded people, train wagons etc.) be electronically marked so that, although moved by hand, their locations might be logged electronically.

Nevertheless, it was agreed among project partners that in the context of the MUSTER system, which incorporates simulations of physical processes and a database in which will be logged resource allocations, the optimal solution to the challenge of providing a visual representation of the site would be to create a virtual reality representation of the site so that the representation could be dynamically linked with *(a)* the physical processes being simulated (fire, smoke and toxic release plumes) and *(b)* the movable objects involved (resources and wounded people). In the following we describe the VR application and its links to the other modules of the MUSTER system.

Virtual Reality terminology

Virtual Reality (*VR*) is an emerging technology, and the definition of what it really is has been widely discussed. As the phrase indicates, the purpose of a VR applications is to simulate the real world, and the final goal is to accomplish this so well that the user cannot tell the difference (confer for instance Kalawsky, 1993). However, today's technology is far away from that goal and we will describe today's standards.

The creation of 3D (virtual) worlds and pre-calculated animation of objects in such worlds falls under the heading of 3D computer graphics - as has been the case for many years and long before VR became known. The distinction between 3D graphics and Virtual Reality can be drawn when the user's exploration of the 3D graphics becomes interactive, that is, when the user can change his/her viewpoint in the 3D world *in real time*, thus simulating that (s)he moves around in the artificial world. Such a movement can for instance be a walk or a drive in a car or a flight in an aircraft.

The main subclasses of the VR concept are *immersive* and *non-immersive*.

Immersive VR entails that the users' senses are (largely) confined to input from the virtual world. This is typically accomplished with a Head Mounted Display (HMD) which to some degree permits the wearer to see stereoscopic 3D graphics and hear artificial sound from the virtual world, and where head movements also change the viewpoint in the 3D graphics. Often this is combined with a glove, giving the user an artificial hand which (s)he can see in the HMD and move and even interact with objects. This gives the user an impression of actually being inside the virtual world.

Non-immersive VR, in contrast, gives the user an impression of moving a *camera*. The 3D graphics are typically displayed on an ordinary (large) screen. There are of course in-betweens, where a glove is combined with on-screen graphics etc. *Desktop* VR is a non-immersive solution where the user moves and interacts with virtual objects through a standard (2D) mouse or the keyboard, and graphics and sound are output to a screen and to loudspeakers, respectively. (See Kalawsky, 1993, and Loeffler & Anderson, 1994, for descriptions of the technologies involved).

Characterization of the MUSTER VR environment

For the MUSTER project we have chosen a non-immersive desktop VR approach. The choice was based on selected real-world aspects of rail-road (and harbour) emergency management. First of all, it has been regarded as important for the achievement of good training effect that site trainees are allowed to use the standard communication equipment, such as portable two-way radios, mobile telephones etc., which they are used to employing during real-world incidents. Our requirement that trainees be able to make use of their standard communication equipment made the choice of non-immersive VR natural. But, secondly, and equally important, was the consideration that current technology is incapable of generating facial movements, so that non-verbal face-to-face communication in general between trainees would be limited. Therefore immersion would be impracticable.
There will be no direct interaction with virtual objects in the prototype version of our application. Though the trainees as such will be limited in their actions, there will be objects like fire and smoke changing in the scene just as trainees will see the effects when they have commanded the movement and deployment of certain resources (fire engines). Therefore, we classify our application as a "Dynamic Walkthrough" (DW). This is on the outskirts of VR but with obvious possibilities of an expansion to real VR (see later). For the purpose of demonstrating the usefulness of VR in training for emergency management, we believe the DW will suffice. See figure 1 displaying a sample illustration from our VR environment.

Let us finally note that the trainees will control their movement around in the scenery as well as the orientation of their view by using input from a mouse or trackball or even a keyboard.

Contents of the VR scenario

We make a partition of objects in the scenery in three classes:
static objects,
dynamic animated objects and
dynamic non-animated objects.
Static objects are objects such as rail-road tracks, roads, buildings and so on, that do not change throughout the

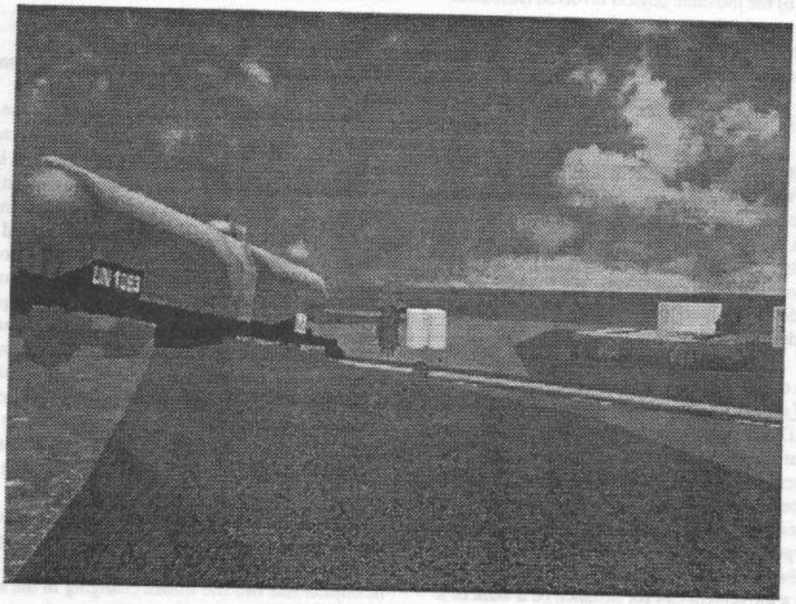

Fig. 1: Sample illustration of the MUSTER Virtual Reality environment

whole session. Dynamic animated objects include fire, smoke and visible clouds of toxic gasses. For obvious reasons these will have to be dynamic, but to give a realistic impression of e.g. fire we add animation. Dynamic non-animated objects are dynamic objects that we felt tempted to animate, but where we fear that animation will add a unsuitable and illusion-thwarting 'computer game effect'. These include fire engines, ambulances and people. They will be inserted on/removed from their changeable locations by a screen refresh when needed.

In one version of the prototype we display some types of crucial information to trainees which they would be getting in a real-world situation from senses other than vision. They include messages telling the trainees that in their current (virtual) location it is "very hot", "air is stifling", " strong acidic smell"; but we are experimenting with ways in which to convey these types of information. Finally, sounds stemming from fire and sirens are reproduced via a sound card and their production linked to appropriate stages of the scenario.

Connections and communication

Apart from the visual representation all communication to and from the VR part of the application runs through the VR database (VRd).

The VRd is a 3D-grid model of the scenario space. The VRd receives and maintains information about placement and behavior of dynamic objects and the placement and orientation of the trainees. It receives information from the Process-data module in an ASCII-file, in 6 tuple format: (o, x, y, z, d, w) where o = object type (smoke, fire, gas), (x, y, z) = placement, d = degree of dispersion and w = direction of wind. The update of VRd is non-continuos in contrast to the real-time change in view-point, that is every one or two minutes VRd receives a new tuple and if the changes concern objects in the field of view of the trainee, the visual representation is updated.

VRd sends information in an ASCII file to the MUSTER Geographical Information System about location and visual orientation of the trainee. This is done in a 3 tuple format: (x, y, o) where (x, y) = location of the trainee and o = orientation angle. This is done to make the exact position of the trainee visible to the training supervisor on his overview screen displaying the GIS application.

Platforms

The development of the VR part of MUSTER is taking place as an integration of high-end and low-end platforms. We have designed the virtual environment using 3D-Studio on Pentium-based PC's. The model of the environment is subsequently ported to dVS on Silicon Graphics' Onyx computers to create the final VR application. Following this approach, we get a highly realistic scenery with almost real-time movement, as mentioned earlier.

Future developments

There are several possibilities and interesting opportunities for stretching the use of VR in training beyond what we have been presenting here. One of the problems mentioned earlier with immersion, namely tacit or non-verbal communication, might possibly be solved by using see-through HMD´s. If so, immersion would become a viable solution and trainees could meet and communicate face-to-face in the virtual environment. Different kinds of training could be performed with the same equipment by just changing the set-up and simulation program. Indeed, we might add teleconferencing and then trainees would not even have to travel to the training site.

For further details about this application readers are referred to Østergaard et al., forthcoming.

REFERENCES

Andersen, H.B., V. Andersen and M.S. Larsen. 1995. "Handling emergency management training scenarios: The MUSTER SCENARIO MANAGER" . *TIEMEC-95*

Andersen, V. and H B. Andersen. 1995. "Multi-User System for Training and Evaluation of environmental Response-MUSTER". In Proc. *TIEMEC 1995*

Balducelli, C., S. Bologna, G. Di Costanzo, G. Vicoli, ENEA, M. Boero, AUTOMA: "A Computerized Support System to Cooperative Training in Emergency Scenarios Management". In Proc. *TIEMEC 1995*

Beroggi, G.E.G., L. Waisel and W.A. Wallace. 1994. "The Role of Virtual Reality technology in emergency management". In Proc. *TIEMEC 1994* p. 212.

Egsegian, R, K. Pittman, K. Farmer and R. Zobel. 1993. "Practical applications of Virtual Reality to firefighter training'. In Proc. *TIEMEC 1993*, p. 155

Gaba, D.M. and A. DeAnda. 1988. "A comprehensive anesthesia simulation environment: re-creating the operating room for research and training". *Anesthesiology* 1988, no. 69: 387-394.

Gaba, D.M., K.J. Fish and S.K. Howard. 1994. "Crisis Management in Anesthesiology". *Churchill Livingstone*, New York.

Jensen, P.F., H.B. Andersen and F.R. Nielsen. 1993. "The Anaesthesia Simulator Sophus". Technical Report (R-Series). Risø National Laboratory, 4000 Roskilde, Denmark.

Kalawsky, R.S. 1993. "Virtual Reality and Virtual Environments". *Addison Wesley Publishers*, New York

Loeffler, C E & Anderson, T, 1994. "The Virtual Reality Casebook". *IT Press*, London.

Schwid, H.A. 1987. "A flight simulator for general anesthesia training". *Computers & Biomedical Research* 1987, no. 20: 64-75.

Østergaard, O, K.O. Hansen and H.B. Andersen (forthcoming). "Training for emergency management using a virtual reality environment". Technical Report (R-Series). Risø National Laboratory, 4000 Roskilde, Denmark.

Vaux, J. 1994. "When does VR need a big machine (or when will a PC do)?"*Expert Systems*, August 1994, Vol 11, No. 3.