

omVR - A Safety Training System for a Virtual Refinery

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Abstract

In this paper we present the prototype *omVR*, which is a Virtual Reality based safety training system for a petrol refinery. It provides an improved technique for personnel safety training and it allows users to navigate through the refinery scenes and to interact with the environment. *omVR* is the implementation of a training environment that immerses the user into a computer-generated reality, which is too dangerous, difficult, or expensive to play in real life. Furthermore, this approach simplifies simulations of accidents and 'what-if' experiments cheaply and without risk.

In our application a trainer has the possibility to control the virtual scene of the trainee from a PC application. This trainer module communicates with the trainee visualization program, which uses Head Mounted Display technology and results a high degree of immersion.

Keywords: virtual reality, virtual environments, safety, training

1. Introduction

Safety, in particular personnel safety, is one of the most important issues in a refinery. The necessity for risk reduction requires good training and education for all refinery employees. Current training environments, like traditional training courses, seminars, etc. suffer from two problems. On the one hand they tend to focus on theoretical issues rather than on practical training. On the other hand practical training in a hazardous environment increases training costs due to safety considerations and related production stops.

A solution is provided by Virtual Reality technology where various training situations can be simulated in virtual environments. The advantages of using VR technologies for a training system can be summarized as follows: First, the VR supported learning is cost effective. As Winn [1] points out, immersive VR technology offers three kinds of knowledge experiences:

1. **Size:** it allows to see and examine all different things in more detail and gives the trainee a new view of the things.
2. **Transduction:** Now, by using VR more human senses can be used for a more realistic training environment.
3. **Simulation:** Finally, simulation defines the possibility to visualize things, which are not

physically present, such as the simulation of different events.

There is an increasing focus on using computer simulators for training systems. Good simulations can provide a wide range of different training scenarios without incurring the high cost and risk.

First, we describe the *omVR* application and we show the advantages of using VR technology for a training environment. Then, we explain the architecture focusing on the trainer and the trainee module. There follows a section with the possibilities for the trainer's interaction and a description of the implementation. Finally, we describe the advantages and benefits of a VE training over conventional training methods.

2. Application

Virtual environment technologies provide a good medium for operation of training systems [2]. *omVR* is the implementation of a training environment that immerses the user into a computer-generated reality (see Fig. 1), which is too dangerous, difficult, or expensive to play in real life. Furthermore, this approach simplifies simulations of accidents and 'what-if' experiments cheaply and without risk [4].

omVR has been designed to foster natural interactions in the training environment with maximum transfer of training skills. The historic methods of field training, which entail high costs and hazardous conditions, can

now be performed within the safe and economical *omVR* environment. Our application uses Head Mounted Display technology (HMD), which results in a high degree of immersion.



Fig. 1 A view to the liquid containers with the manometers, which are controlled by the trainee.

One goal of *omVR* was the simulation of a refinery scenario. In our case it was the training of the employee's behavior in the case of H_2S emission during the daily check in the refinery.

The trainer has the possibility to control the VR scenario by using a PC based application and to simulate different scenarios. Therefore, *omVR* provides training exercises and simulated refinery environments for training specific tasks, situations, and environments that are not feasible due to resources, time, and hazards.

3. Architecture

The *omVR* architecture can be divided into two different modules (see Fig. 2): The *omVR* trainee module, implemented on a graphics workstation, simulates the VR scenario: it gets the tracking input, calculates the new position of the trainee, and visualizes the scene of the refinery. The *omVR* trainer module, implemented in Java, runs on a Windows NT workstation and allows the trainer to control the 3D refinery scene.

One of the most important aspects of our application is that the virtual environment of the trainee can be controlled by the education/training program. In fact, this relationship between the education/training program and the simulation/trainee program is the heart of this educational system.

In the next two paragraphs there follows a closer description of the two programs, the trainer module on the one hand and the trainee module on the other hand.

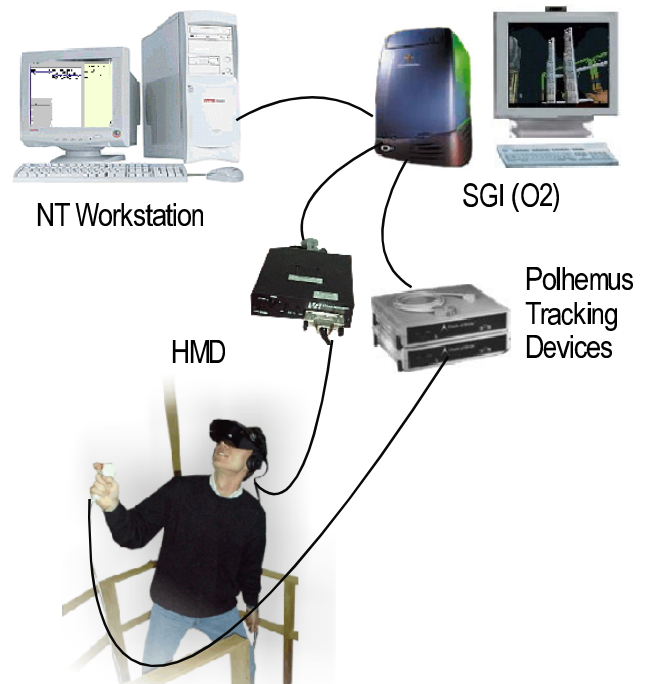


Fig. 2 *omVR*'s simulation runs on a SGI O₂ workstation. The trainer can interact in the refinery scene via the NT workstation.

3.1. Trainer Module

The trainer module was implemented in Java using JDK 1.1.6, it runs on a Windows NT workstation and has two main functions: Firstly, the trainer module allows the trainer control the VR scene (see Fig. 3). Secondly, the trainer can create a protocol for each training session which can also be archived.

While starting a new training session, the trainer can control the VR scene. The indicator of the manometers can be rotated and the water level of the liquid glasses can be modified. Meanwhile, the trainee has to control the function of the pumps and the liquid containers. Depending on the trainee's mistakes during a training-session, the trainer can assign error points, which are recorded in a log file. Doing so, the trainer can perform more training sessions with the same trainee and observe the success or the failure of the refinery employees.

3.2. Trainee Module

The trainer can start the trainee module of the VR workstation from the NT workstation. A model of the refinery was developed and it comprises two areas: the operational area (the refinery) and a tool-room, where the equipment is stored.

When the trainer module has been started, the trainee resides in the tool-room, where there are lying the tools and the working clothes, which can be taken and put on

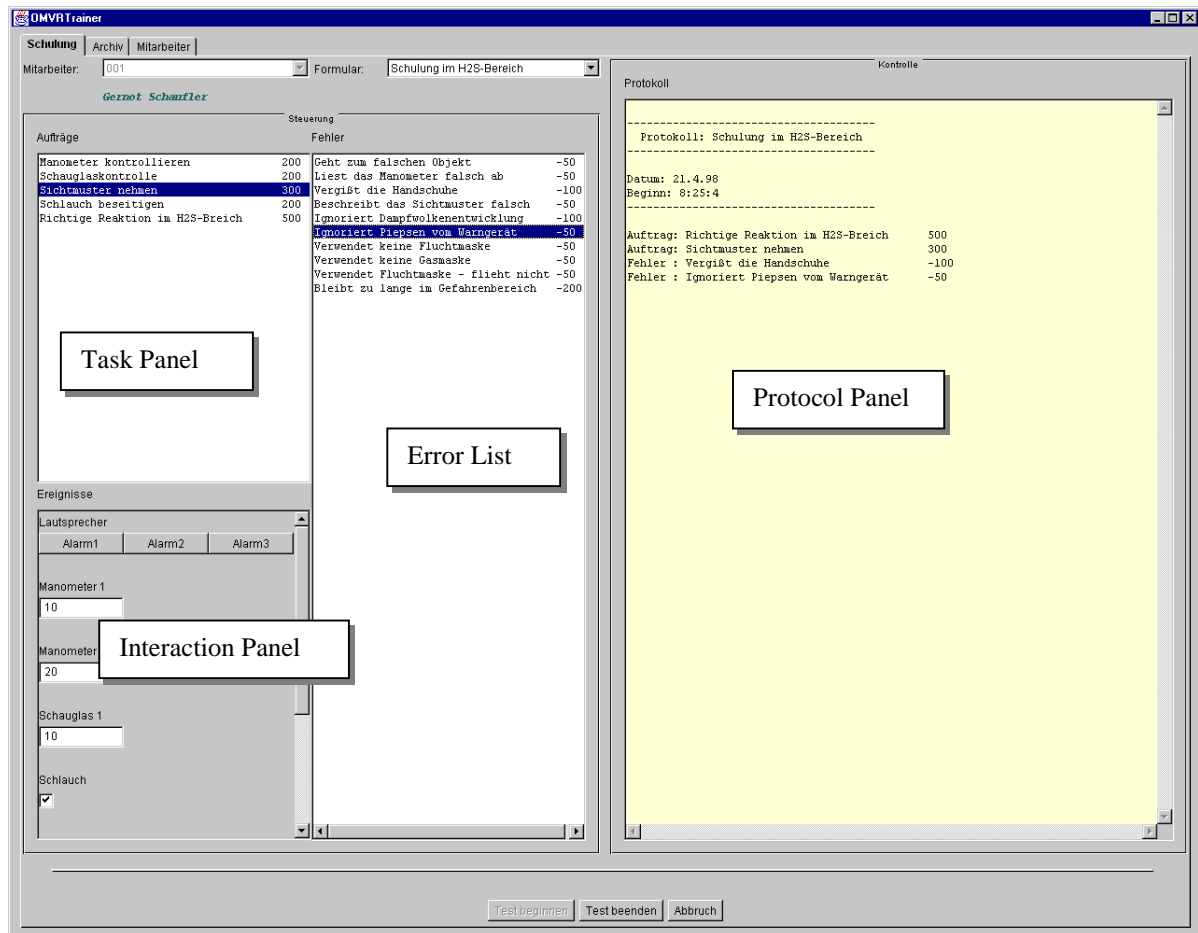


Fig. 3 The trainer program allows a control in the trainee's scene and it protocols a log file.

by the trainee. All the equipment reside in a cupboard and includes:

- Two different types of helmets
- Protective mask
- Escape filter
- H₂S-cheeper
- Radio set
- Two different gloves
- Two different glasses

The trainer can take all these training tools. By clicking to one of these tools, it will be attached directly to the user's virtual belt. By rotating the head and by looking to the ventral, the trainee can see the virtual belt. Not all of the tools and clothes will be attached to the belt. The helmets for instance, or the gas mask will be attached directly to the user's head. When the trainee wants to take off these clothes, the user has to take the joystick, point to the head and push the joystick button. Doing so, the helmet or the gas mask returns automatically to the cupboard or to the virtual belt.

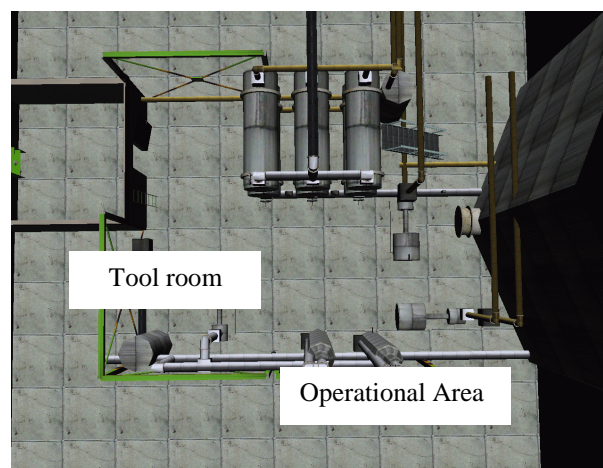


Fig. 4 A bird's eye view of the tool-room and the operational area.

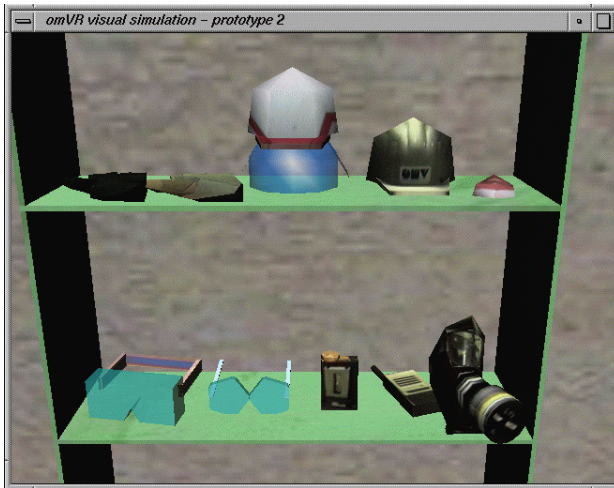


Fig. 5 The cupboard in the tool-room has a lot of different equipment which can be used by the trainee.

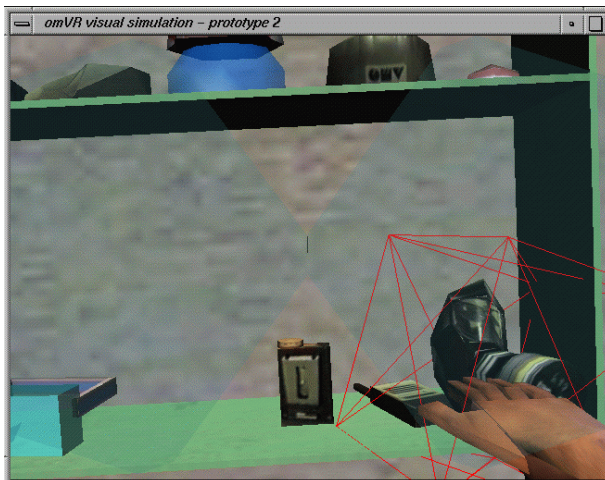


Fig. 6 When the trainee wants to take on the gas mask, the tool has to get the focus. By pushing the joystick button, the user can pick up the gas mask.

The operational area has a limited space, where the user can move. There are different elements, which can be subdivided into elements with a static and with a dynamic attribute:

- Static elements are for example containers, tanks, gasoline stabilizers, heat exchangers, pumps, stairs, and a frame, which circumstance the whole operational area.
- Dynamic elements like the control glasses, manometers, check places for petrol and benzene, and the emission of a steam cloud emphasize the reality of the virtual refinery. The trainee can operate with some of those elements, such as open and close levers, valves, and sliders.

During a training session, the trainee gets different orders confronted with unexpected incidents. Depending on the

task, the trainee has to put on the right equipment and to use the right tools for mastering the situation. The basic equipment of the trainee are the helmet, goggles, gloves, and the radio set. The trainee can execute the following jobs during the training session:

- Control the manometer
- Take a sample of the petrol or the benzene
- Check the control glasses
- React, when the H₂S-cheeper beeps

An imaginable scenario can be as follows: The trainee gets from the trainer the commando to take his equipment and to control the index of the manometer, which has been set by the teacher. So, the trainer has to take on his clothes and to go to the corresponding manometers.

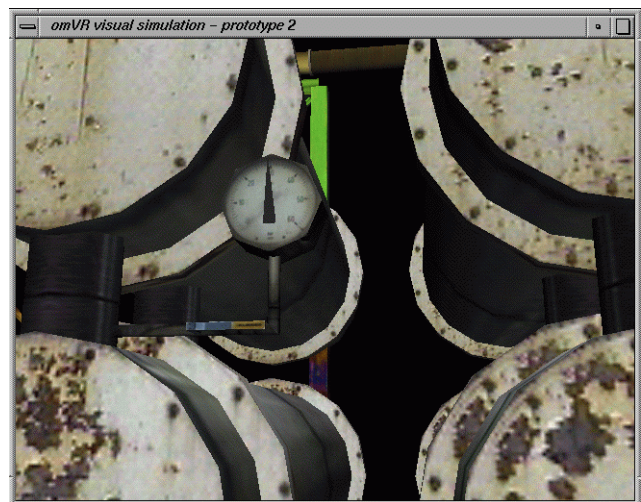


Fig. 7 A manometer is mounted on each heat exchanger and each of them can be checked by the trainee.

After the manometer check, the trainee can be sent to the next operational area, where he has to check and report the booth of the liquid. Of course, the trainer can again modify the size of the liquid pillar. For doing this, the trainee has to pass the H₂S-area. Hence, the user takes on the escape filter or the gas mask and the H₂S-cheeper. If the trainer doesn't have these tools, the user has to return to the tool-room and to take them on. Depending on the trainer's control, the teacher can activate a H₂S steam cloth. Without the accurate equipment the trainee earns penalty points. Nevertheless, when the trainee observes the H₂S emission, the worker has to leave the danger area as soon as possible and only with the protective mask the worker can remain in the H₂S area as long as wanted.

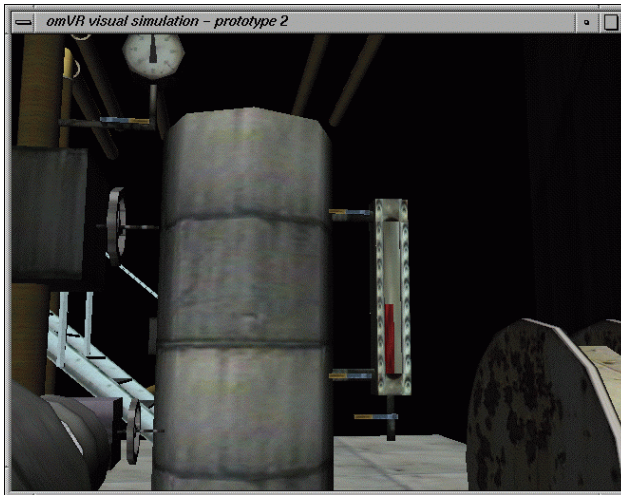


Fig. 8 : The user has to control liquid in the check glass, which is mounted on the container.

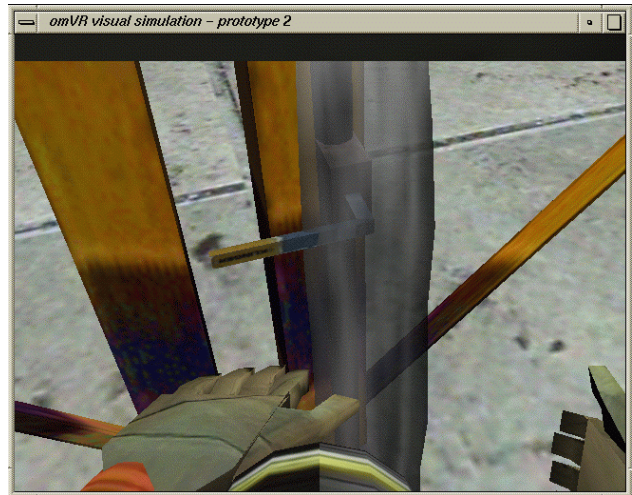


Fig. 10 When the trainee forgets to open one of the levers, the petrol and benzene can overflow.

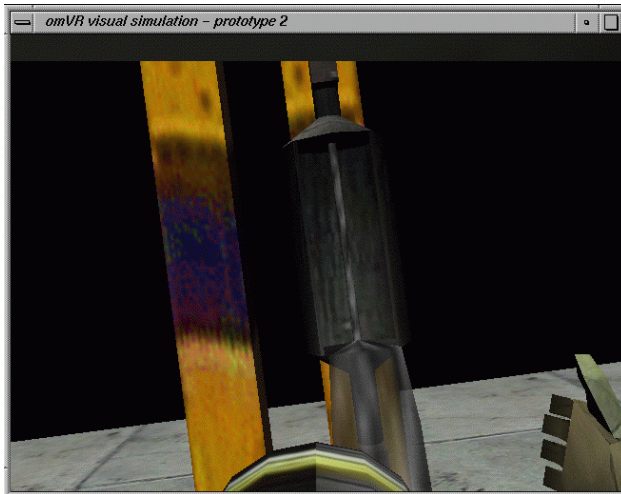


Fig. 9 The petrol and benzene control has to be done with gloves.



Fig. 11 With the protective mask, the gloves and the helmet the user can walk to the danger H_2S area.

Finally, the trainee has to control the check places for petrol and benzene. Therefore, the user has to go to this area and open two different levers. If the trainee forgets to open one of these levers, the petrol overflows and without any gloves the trainee gets penalty points again. In the real environment such mistakes would be fatal and the workers would be cauterized.

One of the goals for the prototype was to define a stressful scenario. Very often it happens that simple and daily things are forgotten by the user. In our scenario, the trainer can drop an grab a hose. In the refinery there shouldn't be any loose equipment on the floor. Therefore, the trainee should grab the hose. The user can do this, by focusing the hose with the hand and by pressing the joystick button.

3.3. Trainer Interaction

Every training session is controlled by the trainer and can be evaluated by a point system. Therefore, there exists a list of all the possible events and tasks in the scenario. The trainer can give orders, activate events and control the 3D world. When the trainee makes a mistake, it will be penalized with minus points, which are listened in an error list. This list has the following entries:

- The trainee forgets to take different tools out of the tool-room.
- The trainee goes to forbidden areas of the scene.
- The user is not able to control and to check the manometer.
- The trainee makes an error controlling the liquid glasses.
- The user ignores the H_2S steam cloud.
- The user ignores the H_2S cheeper.

- The trainee does not use the escape filter or the gas mask.

3.4. Trainee Interaction

To navigate through the virtual refinery, we use a simple joystick as interaction device. The joystick is mainly used for two purposes: the movement and the manipulation of the tools.

3.4.1 Movement

A fundamental requirement for navigating in a virtual environment is the facility to manipulate the effective viewpoint, that is, to move the trainee in the refinery. In our application we used the „fly where you point“ metaphor [3]. This metaphor allows you to proceed in the direction you are pointing, while you are actively looking around in the environment. We find that this metaphor is better than the „fly where you look“ metaphor, where you have to navigate in the direction you are looking.

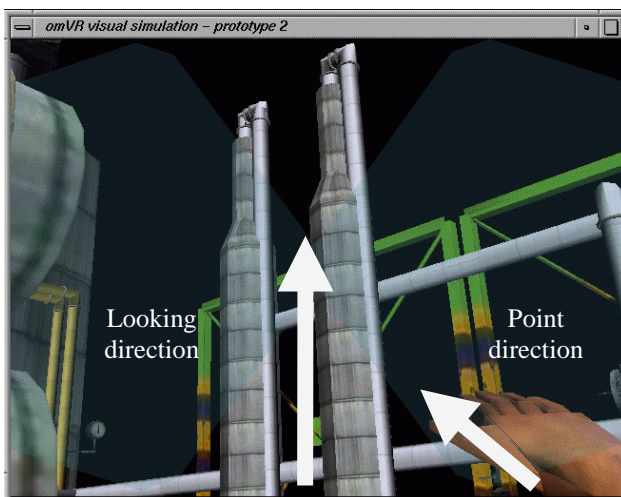


Fig. 12 The looking direction and the point-direction of the hand are not the same. The user moves along the point direction (along the hand).

3.4.2 Interaction and manipulation using tools

When the trainee wants to take on or use a tool, it has to get the focus. If the user does so, the tool gets a red bounding box. Now, the trainee can push the joystick button and the tool attaches itself automatically to the virtual belt (cheeper), to the head (helmets, gas mask) or to the virtual left hand (gloves).

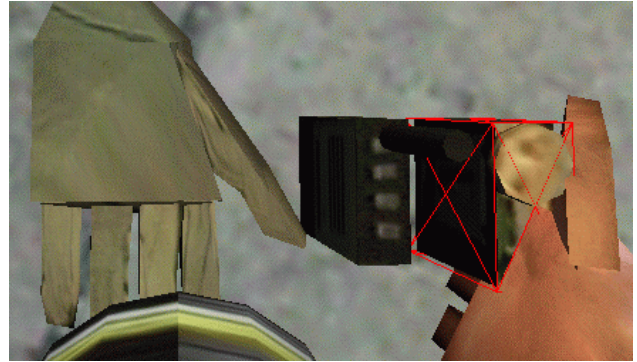


Fig. 13 The virtual belt with a glove and the H₂S cheeper. With the right hand, the user can take and use the tools.

3.5. Sound system

Audio technology, especially three-dimensional sound, enhances the sense of immersion. In our application the pumps produce sounds and engine noises. There are different alarm sounds, which can be activated by the trainer and the trainee has to react in the right way.

4. Implementation, experiments, and results

The omVR program was developed at the Johannes Kepler University of Linz (Austria). The goal was to implement a prototype, which should show the advantages of a virtual safety training system for refineries. To accomplish this goal, the prototype was implemented on a SGI O₂ platform, using IRIX 6.5. Our system supports a HMD, which offers a potential immersion feeling in the virtual refinery.

4.1. Soft- and Hardware

The omVR prototype is written in C++, using the Iris Performer 2.2 graphics library [5] and the Minimal Reality (MR) Toolkit 1.5 [6] for the tracking input devices. The MR Toolkit is a platform system for virtual reality applications, which has been developed at the University of Alberta.

The trainer application, which runs on a NT workstation, is implemented Java using JDK 1.1.6. The sound output is written in C++ and uses the Windows REX sound library which is based on DirectSound [8].

The NT Workstation is a Pentium II computer with 266 MHz and 128 MB of memory. The O₂ has a MIPS R10,000SC processor running at 195 MHz and uses 128 MB RAM. For the tracking system we use the Polhemus 3D Space ISOTRAK II. For the trainee we have the Virtual Research V6 HMD and finally, we use a simple one button joystick for the navigation and interaction.

The Java application communicates with the omVR trainee module using the TCP/IP protocol. The advantages of using Java are the following:

- It is platform independent and therefore it will work on both, UNIX (IRIX, Solaris), and Windows NT.
- A C++ based prototyping is more complicated than the implementation in Java.
- The communication between the two different platforms using C++ and Java is not difficult.

4.2. Experiments

One of the most important goals of the first prototype was to get good performance. While using about 10,000 polygons for the visualization of the scene, we get approximately 15 frames per second on the Silicon Graphics O₂ workstation.

4.3. Results

Tests with a lot of trainees showed that visualizing activities enhances understanding. In fact, efficiency in training delivery was increased. The ability to visualize tasks and events had a very positive impact on the users comprehension of activities.

Very interesting phenomena were the physical side effects such as nausea, oculomotor problems, and disorientation. Users may become so involved in their virtual world that they become unaware and even possibly disoriented with their immediate surroundings. Such a physical trauma occurring during VR use is termed an immersion injury.

5. Benefits of omVR

Beginners are typically overwhelmed by the amount of information and the complexity of the task to be performed. Especially in a real simulation environment the trainees are not able to react in the right way. Because of our virtual environment users are able to skip skilled training sections, which enables them to concentrate on the essential parts of the training. The motivation of the trainee will be increased because the user isn't bothered with well-known training parts. For this reason the overall training time will be reduced.

Summarizing, the benefits and the advantages of omVR as an example for a VR training program are:

- It allows to train situations that would otherwise be too dangerous.

- Applications can be realized, which are so complex that conventional teaching methods are inadequate.
- Trainees get a better understanding of the whole process
- The trainees can learn by doing – they learn from mistakes.
- The learning process is more efficient by an enhanced sense of presence.

Of course we have to point out the disadvantages, too:

- Do workers and trainees find VR interfaces easy to work with?
- Does the effective use of VR technology change the role of the teachers?

Currently, the omVR application is under examination by Austria's biggest oil refinery. The company tested it with many employees and it has been accepted with big enthusiasm as a new training system.

Finally it is possible to train appropriate behavior and decision making under stressful conditions posed by scenarios that represent extreme risk situations [3].

6. Conclusions

In this paper, we have presented a prototype for a safety training system in a virtual refinery.

The results from the present prototype indicated that virtual environments can be effectively used for training in a virtual refinery. It provides a flexible environment where refinery employees can learn unfamiliar situations in the refinery scene, practice tactics and learn how to interact and react in a danger situation.

When compared to other safety training system like the training environment for the Hubble Space Telescope Flight Team [7], omVR is the first virtual reality training program for refineries. We are currently trying to increase the overall performance and to design a modeler tool which allows to create different scenarios.

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