A Metro World Prototype for Virtual Reality Exposure Therapy of Agoraphobia

Fitri Nurdini Rahayu (1116010)

Graduation Committee
Prof.dr. M.A. Neerincx
Dr.ir. C.A.P.G. van der Mast
Dr.drs. L.J.M. Rothkrantz
Prof.Dr. P.M.G. Emmelkamp

Technische Universiteit Delft

Universiteit van Amsterdam

Master Programme Media & Knowledge Engineering
Delft University of Technology
August 2003

Preface

This thesis project consists of:

1. This thesis report
2. The implementation of the Rotterdam Metro Virtual Environment at Mediamatics Laboratory.

This thesis project is done as a requirement to finish the *Master of Science (MSc) Programme Media and Knowledge Engineering* from Delft University of Technology and was done in Mediamatics Laboratory, TU Delft.

During the work I received help from many people to whom I want to express my gratitude:

- Charles van der Mast (Delft University of Technology)
- Martijn Schuemie
- Merel Krijn , Paul Emmelkamp, and Ragnar Olaffson (University of Amsterdam)
- My family and friends that have helped and encouraged me while working in this project.

Table of Contents

Table of Figures

1 Introduction

1.1 Background

Human factors play an enormous role on the software development (Shneiderman, 1998). Human Computer Interaction (HCI) involves the relation between human and computer technology. The user interface (UI) helps users to interact with the computer system. The growing interest on UI design reaches over diverse system. Word processors are used efficiently. Electronic mail and the World Wide Web browser are used as an information source. Many businesses and academics used image-manipulation software. Within software development, there is an increasing awareness for greater consideration to human-factor issues. Researchers are more aware of the need to match human cognitive skills and emotional attitude. Hence collaboration of many researchers from computer science, psychologist, anthropology, etc, may contribute to study of HCI. There are many directions for research on HCI, such as among others input devices, information exploration, direct manipulation (Shneiderman, 1998).

Direct manipulation is one of the forms of interaction between users and a computer system. Direct manipulation uses the representation of reality that can be controlled (Shneiderman, 1998). Direct manipulation interface gives dynamic interaction between user and two-dimensional (2D) objects of interest (Tromp, 1998). Visual interfaces in which users operate are extremely attractive (Shneiderman, 1998). Direct manipulation in computer systems emerged because of the Graphical User Interface (GUI) development. GUI; particularly in using the Operating System (OS), one utilizes lots of direct manipulation interaction. One of the widely known reality representations is the Recycle Bin icon featured in Windows Desktop. If users want to delete a file, they can drag the image or icon that represents the file and drop it to the Recycle Bin. This action represents how people throw their garbage into the bin. New variation of direct manipulation then emerges, such as remote direct manipulation. There are lots of attractive applications of remote direct manipulation in remote application system, such as telemedicine. In one telemedicine scenario, the pathologist can examine tissue samples under a remotely located microscope (Shneiderman, 1998). The pathologist is able to control the microscope by a keypad and see the resulted transmitted image on the screen near the pathologist.

Remote direct manipulation is rooted in two-dimensional space. However, there is correlation between user interaction in Virtual Reality and user interaction in remote direct manipulation because there is a similarity between VR and application with remote direct manipulation. Application with remote direct manipulation and VR breaks the physical limitations of space and lets users to think that they are somewhere else. Therefore VR creates new definition of human-computer interaction (HCI).

Basically, Virtual Reality is a technology that presents three-dimensional (3D) computer generated images for the user to interact with. VR presents potential applications and new emotional territories to its users. Thus there is good prospective of VR applications in the psychology field. New emotional territories introduced by VR are explored and researched in this field. One of new VR applications is phobia treatment with Virtual Reality Exposure Therapy (VRET). VRET puts the patients in the virtual world where they can be subjected to different types of stimuli related to their fear. The therapist will assist the patients in the VRET process.

Mediamatics Department, Delft University of Technology, had done some researches on VRET. Mediamatics, which is mix of mathematical, computer science and information and communication theory disciplines, has Computer Graphics and Human Computer Interaction (HCI) section. There has been a research on user interface design of VR system in Computer Graphics and HCI section, which is conducted by Schuemie (Schuemie, 2003).

VR applications have not been in common use although, as mentioned before, VR has many potentials application. One reason why VR applications are very rare could be caused by lack of research on user interface and interaction techniques for immersive VR (Schuemie, 2003). Therefore research on user interface design of VR system in Mediamatics Department, Faculty of Information Technology and System, TU Delft, plays an important role on VR development in the future. In order to overcome the challenge on designing user interface in VR system, the research focused on a case that is considerably representative for VR application: VRET. For this purpose, Mediamatics Department, Faculty of Information Technology and System, has developed its-own low budget VR system (Schuemie, 2003).

Because the VRET research project has a strong psychological aspect, it includes therapists from faculty of psychology, University of Amsterdam. The project is collaboration between Delft University of Technology and University of Amsterdam. TU Delft is responsible for Human Computer Interaction (HCI) and technical part of the VR, such as developing the system, and University of Amsterdam is responsible for virtual exposure therapy, and any others psychological aspects of VRET research.

To investigate the HCI in VRET, therapists used the VR system to treat patients clinically diagnosed as having phobia. Several virtual environments had been created for this purpose, which consist of:

- Virtual environment for claustrophobia (fear of small space) patients, which illustrates virtual hallway, closet, and elevators.
- Virtual environment for acrophobia (fear of height) patients, which illustrates virtual fire stair, rooftop terrace, and magna plaza (a mall in Amsterdam).
- Virtual environment for fear of flying patients, which illustrates virtual flight and airport.

1. 2 Problem Description

As mentioned before, the therapists from University of Amsterdam has used the VR system to treat phobia patients using VRET method. Using the VR system, they have done a comparative evaluation on acrophobia (fear of height) VR treatment versus exposure in vivo (Emmelkamp et al., 2002). The research tests the effectiveness of VRET. The result showed that VR exposure to the acrophobia patients was found to be as effective as exposure in vivo. Learning how phobia treatment VRET can support clinical therapy is very interesting. VRET also shows advantages over the traditional way of clinical therapy. For example, the therapist can easily treat the patient in his office. Because of this positive result, more VRET phobia treatment research for other kinds of phobia, beside acrophobia, are highly demanded. Then the virtual environment for claustrophobia and fear of flying VRET are developed to accommodate this necessity.

However there hasn't been any research on agoraphobia VRET using the VR system developed in Mediamatics Department, TU Delft, although therapist from University of Amsterdam received lots of case regarding people who suffer agoraphobia. Therefore they suggest me to develop new virtual environment intended for agoraphobia VRET.

To develop a virtual world for agoraphobia VRET, the therapist suggested virtual world that illustrates:

- Magna Plaza, which is a mall in the Amsterdam.
- Airport.

- Public transportation.

Because of time limitations, I will only develop one virtual world for agoraphobia VRET. Therefore we have to decide which virtual world that is going to be developed from the choices offered by the therapist. Because VRET research is still in experimental phase, we would not know which virtual world that would give the best result in agoraphobia treatment using VRET. The decision factors are solely based on VR system capability and therapist preference (Rahayu, 2003). From time point of view, modifying the Magna Plaza and airport world so that they can be used for agoraphobia VRET seems a better idea than developing public transportation world from scratch. However modifying old world will make them more complex. Adding more complexities to the virtual world is also adding the risk of rendering problem. Because of this uncertainty, it is decided that developing the new world from scratch will be better. There are four choices of public transportation world that can be developed for agoraphobia VRET. They are:

- Bus world
- Tram world
- Train world
- Metro world

Based on the therapist preference, we will develop virtual metro world for agoraphobia VRET. (Rahayu, 2003)

1.3 Research Goal

As mentioned before, I will develop a virtual metro world for agoraphobia VRET for my master thesis project. The virtual metro world will be modeled from Rotterdam Metro. This world will be a prototype virtual world that is open for improvement. The therapist will give valuable suggestion for the development of Rotterdam metro virtual world. Hence, this leads to the research goal as follow:
"The design of a prototype Rotterdam metro virtual environment for agoraphobia VRET using the Virtual Reality system developed earlier and evaluates it."

1.4 Research Method

1.4.1 Design Method

Because the metro world for Virtual Reality Exposure Therapy (VRET) of agoraphobia had never been developed before, it was decided to build the first application using prototyping in iterations. The final prototype of the application will be based on several earlier versions of the prototype. The final prototype will be an improvement of the earlier version of prototype. The improvement will be based from the therapist's input as the VRET users.

To design and develop the metro virtual world and the therapist's user interface, method of Foley and van Dam is used. Method of Foley and van Dam used the four-level approach as follow (Shneiderman, 1998)

1. The conceptual level.
   It is the user's mental model of the system.
2. The semantic level.
   It describes the meanings expressed by the user's input and by the system's output/display.
3. The syntactic level.
   It defines how semantic level is assembled into a certain task in the system.
4. The lexical level.

1.4.2 Evaluation Method

Designers are very close with their creations. Therefore they may unable to evaluate their creations objectively and adequately. Therefore some kinds of testing or evaluation are a necessity. There are several evaluation possibilities (Shneiderman, 1998). Expert reviews and surveys are some of the evaluation technique. One evaluation method will use the therapist input. The therapist will give some input after viewing metro virtual world for VRET of agoraphobia.

Then the final prototype world will be experimented on several people. These people will have to answer some questionnaires after taking the 'virtual journey' with the metro. The evaluation will measure the sense of presence that they experience. It can be use to measure whether people feel what agoraphobics are afraid of, which is the feeling that they are in the real metro. Low sense of presence means that they don't feel that they are in the real metro.

1.5 Report Outline

This report will start with the introduction, which is located in this chapter. The introduction covers the background and problem description of my master thesis project. Research goal of the project is also mentioned here. The research method is also discussed here.

In the chapter 2, some backgrounds related to the Virtual Reality Exposure Therapy will be asserted. This chapter will cover some terms used in VR. It also will briefly discuss presence. Last but not least, agoraphobia and its treatment will be addressed too.

Chapter 3 of the report will describe the VR system used in the master thesis project.

Chapter 4 will discuss the design of Rotterdam metro virtual world. The design process will consist of several phases. Then the experiments of the metro virtual world will be discussed in the next chapter leading towards the outcome of the design.

The report will be closed with the conclusions.

2 Virtual Reality Exposure Therapy

2.1 Virtual Reality

2.1.1 Introduction

Virtual Reality (VR) is a quite famous terminology nowadays. It mainly caused by entertainment industry. VR technology is often mentioned and portrayed in science fiction movies or books. However most of the VR portrayal is slightly accurate because lots of movie or book featured director or author fantasy about VR technology instead. Some of these movies and books became a cult hit, which made the VR terminology widely well known. Thus VR terminology is able to attract public eye. Public fascination of the VR mainly caused by the illusion of being in a different place rather than in the real world, which is able to exercise and challenge public's imagination.

Because VR portrayal often slightly accurate, most of public do not know exactly what is VR and what equipment is used although they have heard VR. Therefore, this section will cover about VR technology. I will give the broad overview about VR.

Virtual Reality is a complex technology. Creating a working VR application is a difficult job because it needs broad range of knowledge, such as 3D computer graphics, programming, computer hardware, and VR equipment. Few complete off the shelf VR system bundles also makes the VR application development harder (Isdale, 1998).

2.1.2 Virtual Reality Terms

There are many different definitions of Virtual Reality. 'Father' of Virtual Reality technology, Ivan Sutherland, did not use the Virtual Reality terminology. Jaron Lanier first uses virtual Reality terminology in 1980 (Bryson, 2003). Ivan Sutherland used the Virtual World terminology instead, which he defined as "The ultimate display would be a room within computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the wonderland in which Alice walked." (Harrison, et. al., 1996)

Cambridge Dictionary defines Virtual Reality as a set images and sound produced by a computer, which seem represent a place or situation that a person can experience or take part in.

Jerry Isdale defines Virtual Reality as a computer generated image, 3D spatial environment in which users can participate in real time (Isdale, 1998).

One of the simple definition: Virtual Reality is a 3D computer generated world with which users can interact (Kooper, 1994). There are different types of interaction, from looking around to interactively modifying the world.

The use of computers, displays and sensors to create the illusion that the user is in another environment than the real one, in a Virtual Environment (VE) is the definition from Martijn Schuemie (Schuemie, 2003).

All definitions mentioned above show the central theme of Virtual Reality. Virtual Reality involves real time 3D computer generated images. Users are also able to interact with the 3D images. With the help of computers, displays, and sensors, the images will give illusion to the users as if the users are in another environment.

2.1.3 Some Related Technologies

2.1.3.1 3D Images versus Virtual Reality

Basically, VR is 3D computer generated graphics with which users can interact. Thus, VR technology exists because of computer graphic technology. The computer graphic technology evolved fast nowadays. Lots of today's application use 3D computer generated graphics, such television programs and special effects in films. Today movie can generate amazing and impressive 3D computer generated graphics that looks like real. But are they Virtual Reality? The answer is no, they are not (Vince, 1998).

They are not considered VR because there is no interactivity involved. The actors doesn't involve directly with the 3D virtual objects or virtual actors, such as monsters. Example of the famous virtual actors is illustrated in figure 2.1. When shooting live action scene, actors pretend that the virtual objects or virtual actors are with them. Then at the post-production stage, the 3D computer generated elements are integrated with the live action scene to produce the final film. One of the most successful final scenes comes from battle scene in Lord of The Rings movie. Thus, there are not any forms of interaction between actors with the virtual objects (Vince, 1998).

Fig 2.1 Gollum, the award winning virtual actor from Lord of The Rings
(Courtesy of www.lordoftherings.net)

Computer generated special effects are good example of computer animation, which is another and different subject with VR.

2.1.3.2 Telepresence

Telepresence technology is one variation on computer generated visualization technology. The technology connects remote sensors that capture the real world with human operator located on the other side of the world. These sensors might be placed on a robot. This robot had been used in Mars exploration. Fire fighters also use remotely operated vehicle to handle dangerous situations.

2.1.4 Types of Virtual Reality

There are different types of VR systems. This classification based on the mode with which they interface to the user. Some common modes are as follow (Isdale, 1998)(Vince, 1998):

2.1.4.1 Immersive Virtual Reality

The best VR systems are the systems that are able to immerse the users in the virtual world. Users' personal viewpoint immersion can be achieved by using these two following equipment:

- Head Mounted Display (HMD). This device, which looks like a heavy face mask, holds the visual and auditory display.
- Cave. It is created from multiple large projection display. Therefore when a user stand inside the 'CAVE', which is similar with a room, the user will be able to be immersed by visual display that surrounding him or her. In a nutshell, think of Holodeck technology from Star Trek series. Holodeck is a future version of CAVE technology.

Navigation in Immersive VR uses a tracking device to track the position user's head in three dimensions space. Hence, when the users turn their head, they can see the objects that are beyond their Field of View (FoV). They will also pass the objects that are no longer in front of them when the users move forward or backward.

2.1.4.2 Desktop Virtual Reality

Desktop VR uses conventional monitor to display the visual world. The concept is started back to the father of VR, Ivan Sutherland.

Desktop VR or non-immersive VR uses different kinds of navigation. As in the immersive VR, users wish to move around the virtual world. In the immersive VR, this goal can be achieved by moving your head or your body because sensors are attached into parts of your body and a tracker will detect your movement. Thus special interface tools are required. One solution is to use a joystick or 3D mouse. Another way that has been successful with web browser is to use two or three screen controls that work in combination with a conventional 2D mouse.

2.1.5 VR Hardware

Hardware mentioned in this section, is generic device that is used in the various VR system. VR system usually consists of several types of hardware. They are (Isdale, 1998) (Vince, 1998) :

2.1.5.1 Computers

There are different kinds of computer: from PC to parallel supercomputer. Nowadays, all computers are able to generate pictures. Hence they are all candidates as a VR platform. Generating images is a very important and also a very time consuming task. However, the generation real time 3D images depend on the processing ability of computer. The processing limitation will ultimately determine the complexity of 3D images that the computer can manipulate. Basically, VR systems needs computer with powerful processor and high performance graphics board.

2.1.5.2 Tracker

Tracking position of a real object, such as head is important because it supports one key element of VR: interaction. In some applications, monitor the real time position and orientation of user's arm is required and in some instances the entire body. Ideally, the tracker is able to provide three measures for position (X,Y, Z translation) and three measures for orientation (roll, pitch, yaw).

There are different technologies of tracker that is currently used in VR. They are as follow:

- Mechanical

Mechanical tracker can be used to give fast and accurate tracking. A simple mechanical tracker may take the form of mechanical arm jointed at the shoulder, elbow and wrist. It may look like a desk lamp. However the mechanical trackers has restriction on motion. Another drawback is the burden of the device.

- Ultrasonic

Ultrasonic trackers utilize ultrasonic sound to track position and orientation. The advantages of ultrasonic tracker are simple, effective, accurate and low cost. The disadvantages of ultrasonic tracker are low resolution, long lag times, sensitive to temperature, and interference from echoes and other noises.

- Magnetic trackers

Magnetic trackers system utilizes sets of coils that are pulsed to emit an electromagnetic field and a sensor that detect the radiated field. The electromagnetic field source, which can be no bigger than a 2 inches cube can be placed on a table or fixed to a ceiling. The sensor that determines the strength and angles of the fields, is smaller than the source and is readily attached to a HMD or fitted within a 3D mouse. Magnetic trackers seem to be one of the popular trackers.

- Optical trackers

One method of optical trackers is using infrared video cameras that records and captures movement of a person. Limitation factor for optical tracker is processing time because optical tracker needs high speed computer to track object

- Inertia tracker

Inertia tracker utilizes the Earth's gravitational or magnetic field for rotational measurement. However it cannot determine object's position. Thus, its application is limited in VR.

2.1.5.3 Manipulation and Control Devices/Input Device

There are different kinds of control hardware. The simplest ones are conventional mouse, trackball, or joystick. Market also has introduced 3 and 6 dimensional mice, trackball, joystick devices at this time. There are some extra buttons and wheels that used to control translations and rotations in Z direction, not jus XY direction.

Another common VR device is the instrumented glove, which is used to manipulate objects in the virtual world. The glove is outfitted with sensors and tracker on the fingers. The glove is made from a lightweight material into which transducers are sewn. The transducers are employed to measure finger joint angles for monitoring fingers orientation. Extra tracker is put in the wrist to monitor the position and orientation of the hand. Thus Virtual Environment (VE) can animate the virtual hand.

The concept of a glove has been extended to other body parts. Motion capture technology uses full body suits with position and bend sensor for capturing motion for VR applications as well for character animation etc.

2.1.5.4 Display

- HMD

HMD closely associated with VR. It uses goggles to lay display in front of the eyes. There are different kinds of HMD offered in the market based on the price range. Better HMD has higher cost. Most HMDs use two displays and can offer stereoscopic imaging.

- CAVE

It is assembled from several of back projection screens with display system. The user inside the CAVE wears shutter glasses in order to see stereoscopic view everywhere.

- Virtual Table

Its construction is similar with table. The screen of virtual table is its tabletop, which consists of a glass or plastic screen.

2.2 Agoraphobia and Treatment

2.2.1 Anxiety Disorder

Anxiety is normal (Social Anxiety Association, 2003). People will have mild and brief anxiety sometimes. The anxiety may be caused by first date, important presentation, job interview or first day at school. However if the anxiety is chronic, it becomes a serious medical illness. It is called anxiety disorder, which may influence adults and children. If it is not treated, the illness will grow gradually worse. Anxiety disorders are the most common psychiatric problem.

There are different kinds of anxiety disorders (National Institute of Mental Health, 2003):

- Generalized Anxiety Disorder (GAD)
  A person who suffers GAD is a pessimist person. They anticipate the worst so that they worry too much about money, job, family, or health. Hence they cannot relax, which sometimes lead to physical symptoms, such as nausea, headache, fatigue, muscle tension or trembling.

- Obsessive-Compulsive Disorder (OCD)
  People with OCD cannot control the repetitive and obsession behaviors. The repetitive behaviors, such as counting or cleaning are intended for making the obsession go away. However it only gives a temporary relief. If the repetitive behaviors are not performed, the anxiety will increase. Both children and adult can suffer OCD.

- Panic Disorder
  People with panic disorder usually develop it in late adolescence or early adulthood. Panic disorder is distinguished with intense fear that attacks often and repeatedly. It is accompanied with physical symptoms such as chest pain, dizziness, shortness of breath, fear of dying, or abdominal distress. The symptoms sometimes imitate life-threatening medical conditions, such as heart attack.

- Post Traumatic Stress Disorder (PSTD)
  It is an anxiety disorder that happens after experiencing frightening events, such as assaults, disasters, or wars. These events are traumatic events for the victims. They will

trigger PSTD to the victims. Family members of victims sometimes also develop PSTD. People with PSTD may have nightmares, flashbacks, numbing of emotions, depression or feeling angry as the result of their illness.

- Phobias
  Among anxiety disorders, phobias are the most frequent ones (National Institute of Mental Health, 2003). Phobias are divided into two major types. They are specific phobia and social phobia. A person, who has specific phobia, has irrational fear of something that has little or no real danger. There are several types of specific phobia. Some of them are fear of height, fear of spiders, fear of flying, fear of closed-in places, and agoraphobia. People with specific phobias will get panic attack or severe anxiety when they face or think about confronting the feared object or situation.

2.2.2 Agoraphobia

Agoraphobia comprises intense fear and avoidance of any situation or place where escape might be difficult and embarrassing. They also have problems in the situation from which help may not be available when a panic attack hit them (National Institute of Mental Health, 2003). Therefore they tend to have these following behaviors (Psychology Today, 2003):

- Avoidance of these following situations: traveling in a car or public transportation, being in crowded area, being alone outside of the home.
- Needing another person's company, such as family member or friend when they go to the place that they fear.

Agoraphobia sufferers are seriously disabled by their 'condition'. They may be unable to work, to shop, etc. They will rely heavily on another persons for shopping or traveling outside their house. People with agoraphobia may stay in their house for years, resulting impairment of social relationship. Hence they live a life of great discomfort and extreme dependency.

2.2.3 Treatment for Agoraphobia

Cognitive Behavior Therapy (CBT) is a therapy that combines two type of psychotherapy: cognitive therapy and behavior therapy. Cognitive therapy trains the patients about particular thinking patterns, which cause symptoms, by making the patients to feel anxious. Behavior therapy assists the patients to conquer the relation between upsetting situations and patients' habitual reactions to them. Therefore changing the ways of thinking is the cognitive aspect of CBT. On the other hand, aiding a person to face the challenge, which may scare his or her, with clear and calm mind is the behavioral aspect CBT. Generally, CBT has been proven to be a better treatment for anxiety disorders than using drugs because CBT is able to avoid treatment failures and relapse that may occur after finishing the treatment (Cognitive Behavior Therapy, 2003).

Exposure therapy is the main component of CBT for phobia patients. The patients will be presented with situation that feared them most so that in the end, the patients will become comfortable with this situation. The exposure will be gradual and will consist of several stages. Earlier stages will be easier to handle by the patients. After overcoming the easier situations, the patients will be taken to more difficult situations (Cognitive Behavior Therapy, 2003)(Social Anxiety Association, 2003).

The conventional method of exposure is in vivo exposure. However, there is a new type of exposure for curing phobias. It is Virtual Reality (VR) exposure. From the study of Virtual Reality treatment versus exposure in vivo for acrophobia (fear of height) conducted by Department of Clinical Psychology, University of Amsterdam and Delft University of Technology, it is found that VR exposure is as effective as exposure in vivo (Emmelkamp et al., 2002). Because of the success of VR exposure for acrophobia treatment, VR exposure will be developed for other kinds phobia, such as agoraphobia.

2.2.4 Current Agoraphobia Virtual Exposure Therapy Project

Virtual Reality for curing phobias is still in early stages. However there are several researches that have been conducted regarding this topic. Various studies have been carried out to validate the effectiveness of virtual reality and phobia. Some of them are Virtual Reality researches for curing agoraphobia. This part will cover other researcher's projects about VRET of agoraphobia. There are several researches that will be mentioned. Information of those researches will include these following important topics:

- System for VRET of agoraphobia that has been developed. The information will contain hardware and software components. However because this information depends heavily on the literature source that I got, some of the information may be not in detail.
- Virtual Environment that is used to the patients/subjects who have or agoraphobia.

.
The VR system information that has been acquired will be compared in the end.

2.2.4.1 Biomedical Engineering Department, Hanyang University, Korea

Hardware Components

The VR system in the research on VR and agoraphobia used this following hardware:

- Head Mounted Display (HMD)
  HMD used here is Provies TM XL50, Kaiser Electro-Optics Inc, with1024H X 768V, and 50 degrees diagonal.

- An electromagnetic tracker.
  The research uses FASTRAK tracker from Polhemus, Inc. Its role is as a head tracker that is used for position or orientation measuring. The tracker computes the position and orientation of a tiny single receiver as it moves through space. The data update rate of single transmitter is 120 Hz. It gives dynamic and real time six degrees of freedom measurement of position and orientation. The position is measured in X, Y, Z Cartesian coordinates and orientation is measured in pitch, yaw, and roll. RS-232 and USB is used as an interface to the PC. The FASTRAK tracker uses low-frequency magnetic transducing technology so that the line of sight between receiver and transmitter does not have to be clear in order to transmit data well.

- Drive Simulator (TM Nascar Froce Pro, Thrustmaster, Inc)

- BooDoo (3D accelerator) for real time imagery

- PC with Pentium processor

Virtual Environment

The VRET experiments by Hanyang University, Korea, for agoraphobia exposure treatment used these following environments:

- Balconies
- Empty room
- Dark barn

- Dark barn with black cat
- Elevator
- Subway
- Tunnel with traffic jam
- Airplane
- Public speaking
- Theater

2.2.4.2 Virtual Reality Medical Center (VRMC)

Virtual Reality Medical Center is medical center that uses virtual reality to treat people who have phobia. It is not a research center. Therefore research on developing virtual reality system is not available here. VRMC also doesn't explain how effective and successful the treatment is. VRMC only offers to treat several types of phobia, including agoraphobia. VRMC has virtual environment that can be used for agoraphobia exposure treatment. The procedure of the treatment, in a nutshell, is illustrated in the figure 2.2 (Virtual Reality Medical Center, 2003).

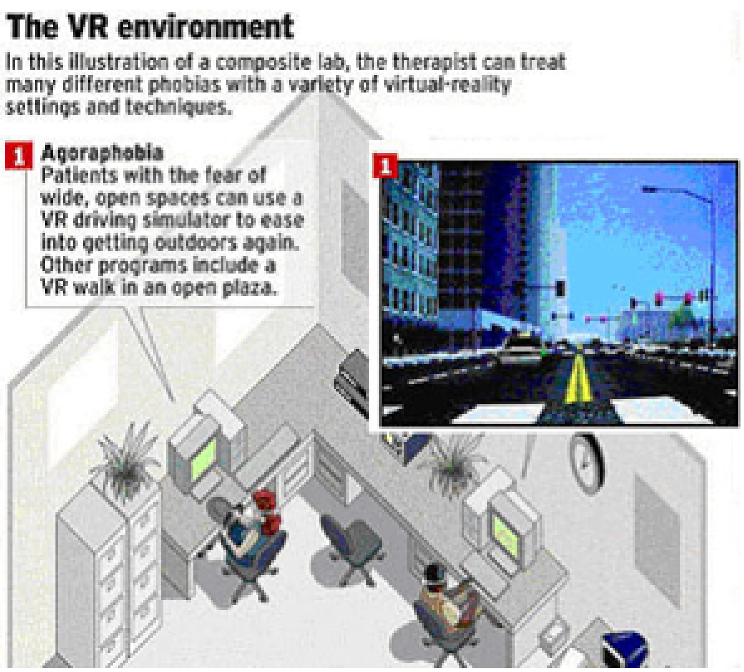

Fig 2.2 Illustration of VRET in VRMC

These following pictures (figure 2.3 and figure 2.4) are the screen captures of the virtual environment, which are used for agoraphobia treatment.

Fig 2.3 Virtual environment for agoraphobia

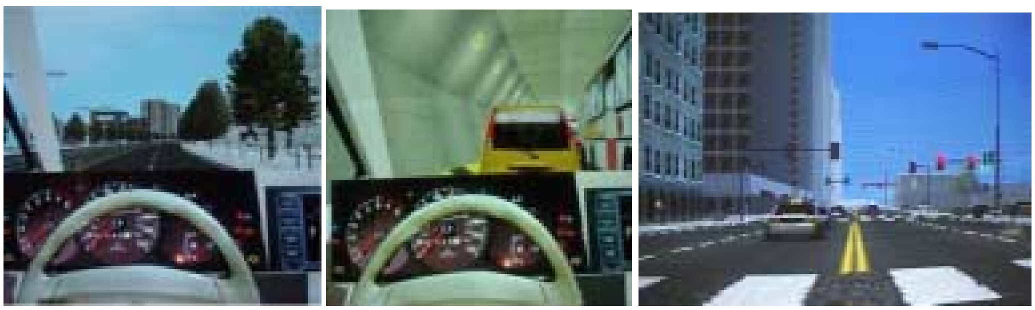

Fig 2.4 Virtual environment for agoraphobia

2.3 Presence

2.3.1 Introduction

Virtual experience can evoke the same reactions and emotions as a real experience. Several researches showed that VRET therapy is as effective as in-vivo exposure therapy. One success result comes from fear of height VRET research (Emmelkamp et al., 2002). The effectiveness of VRET therapy comes from the fact that virtual environment can trigger the patient's emotion such fear. It means that VRET is able to affect the patients' in the non-cognitive way. It seems that presence gives a high contribution to the success of phobia treatment using VRET because a key element of Virtual Reality is the concept of presence (Hodges et al, 1994).

2.3.2 Definition of Presence

There are many definitions of presence. Some definitions will be mentioned in this section in order to get the general idea, what is presence.

Lombard and Ditton (Lombard, 2003)
Presence is not a terminology that only related to the Virtual Reality. Lombard and Ditton recognized six different meaning of presence that had been used in literature. They are:

- Social richness
- Realism
- Immersion
- Transportation
- Social actor within medium

The meaning of presence that relates to the immersive VR is presence as transportation. It is the sensation of 'you are there' and 'it is here'.

Schloerb (Schloerb, 1995)
Schloerb differentiate two kinds of definition. They are:

- Subjective presence, which is how a person determine himself to be physically present in the virtual environment.
- Objective presence, which is the possibility of finishing a task.

Slater and Wilbur (Slater, 1997)
Both of them make a distinction between presence and immersion term. They define that immersion is an objective description of the system such as field of view and display resolution. On the other hand, they define presence as a subjective phenomenon such as the sensation of being in a virtual environment.

However Witmer and Singer did not agree with the definition of presence proposed by Slater and Wilbur because immersion term is occasionally used in a way similar with the subjective definition of presence (Witmer & Singer, 1998).

Definition that came from Slater and Wilbur will be used in this thesis project.

2.3.3 Presence and VRET

Presence as the sense of being in a virtual environment is essential part in the phobia treatment using VRET because this type of treatment depends significantly on whether the patient can confront with the situation that they fear of. If the patient does not feel presence in virtual environment, he will not be afraid in the virtual environment because there will be no stimuli that provoke his fear.

Presence makes a virtual experience that is able to evoke the same reactions and emotions as a real experience. Hence it is the most significant consequences of presence. The success of treating phobia by VRET is caused by presence because presence can make emotional responses similar with the real world. Presentation by Mark Wiederhold at the MMVR2002 conference, Newport Beach, California showed that *lack of presence is the main reason that VRET fail* (Schuemie, 2003)

One problem related to VR simulator sickness. It is an event that comes from using VR. Lots of reported case shows that using VR can cause nausea and dizziness to the user. Witmer and Singer (Witmer & Singer, 1998) found a negative correlation between simulator sickness and presence. On the other hand Slater (Slater et al, 1993) found a positive correlation between simulator sickness and presence

2.3.4 Measuring Presence

There are two kinds of presence measurement:

- Objective measures, which consists of Behavioral and Physiological
- Subjective measures. Subjective measures uses questionnaire as the mean of introspection by the subject.

In this thesis, we are going to use only the subjective measures for determining the degree of presence in the metro virtual world. There are various questionnaires developed for the purpose of presence measurement. One of the well-known questionnaires is Igroup Presence Questionnaire (IPQ), which is developed by Schubert (Schubert, 2003). They develop the IPQ based on the previous published questionnaires. IPQ combines previous published questionnaires, such as questionnaires developed by Witmer & Singer and developed by Slater & colleagues. The presence factors in IPQ are:

- SP (Spatial Presence), the relation between the virtual environment as a space and the own body.
- INV (Involvement), the consciousness in the virtual environment.
- REAL (Realness), the sense of reality in the virtual environment

Schubert & colleagues analyzed the internal consistency of IPQ over two studies to be 0.85 and 0.87 (Cronbach's α; N= 264, N=296).

3 VRET System and Environment

3.1 Introduction to The Current VRET System in TU Delft

3.1.1 Hardware Components

Mediamatica department had developed a pilot system for VRET. The Virtual Reality (VR) system is made for prototype purpose. The VR system consists of the off-the-shelve components. Therefore it is easy to maintain, flexible, and the cost is not too expensive (Schuemie, 2001)(Schuemie, 2002). The hardware components consist of:

- <u>Head Mounted Display (HMD) and Control Box</u>
  HMD supports interactivity for VR system. The interaction is enough to create natural feeling of interaction for the user. Quality of the visual display of the HMD determines the vividness that relate to the sense of presence. The quality of the display is determined by resolution and Field of View (FoV).
  HMD used in the system is Visette Pro, which is manufactured by Cybermind. It is quite expensive HMD. Advantages of this HMD is:
  - It has 70 degrees Field of View (FoV). Common Fov of HMD is about 25 degrees.
  - It supports stereoscopy. It means that each eye gets an image from slightly different viewpoint by taking into the distance between eyes. Stereoscopy can increase the sense of presence.

  This type of HMD also has disadvantages
  - It is heavy (around 2 kg)
  - It has low resolution (640*480)

- <u>Flock of Birds</u>
  Tracking system used in the system is an Ascension Flock of Bird (FoB) tracker. It makes the computer able to track the orientation and the location of HMD. It consists of:
  - Transmitter for creating a magnetic field
  - Sensor, which is built in the rear of HMD to measure the magnetic field
  - Control unit. It uses data from the sensor to calculate the translation and rotation, and then it is fed to the computer using serial connection RS-232.

  The transmitter must be placed near the sensor because it has constraint range, about 4 feet. The transmitter also must be placed where user cannot move it in order to prevent the coordinate in the system from flipping that cause jump of location informed by the tracker. Jump of location may occurred because the coordinate system of the tracker is divided into two hemispheres that are divided by the plane going through the transmitter perpendicular to the cable attached to the transmitter. This plane is illustrated in figure below. Therefore if someone moves the sensor to another hemisphere, the coordinate system will flip.

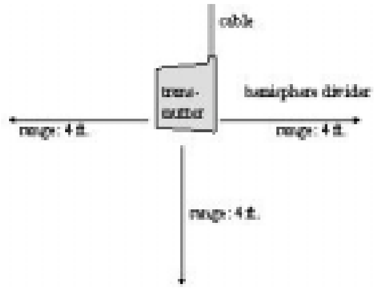

Fig 3.1 Flock of Birds transmitter view.

- <u>Bass amplifier</u>
  It is used to amplify sound for creating vibration effect in the seat of plane, for creating the effect of taxiing and flying plane. The amplifier is connected to audio-out of PC and speaker connector for connecting to the vibration devices placed near the plane seat.

- <u>Intergraph PC</u>
  Because of using stereoscopic HMD, two synchronized VGA outputs are required. PC with Pentium 2 450Mhz processor PC with graphics card: 3DLabs Oxygen GVX420. The graphic card hast two VGA outputs whose vertical retrace is synchronized. In order to create an output on VGA connectors and show display in HMD, screen resolution in windows must be set to dual resolution 1280x480 (two times 640x480). Intergraph PC is dedicated solely for displaying Virtual Environment (VE) in the HMD.

- <u>PC</u>
  This is the second computer that uses standard 3D card for controlling the VE over the IP-based network. Therefore this PC, which is used as the therapist's user interface, can have a long distance connection with the Intergraph PC.

- <u>A Logitech wireless trackball</u>
  It serves as an input device for the patient or subject that wears HMD.

Figure 3.2 illustrates how the components are connected.

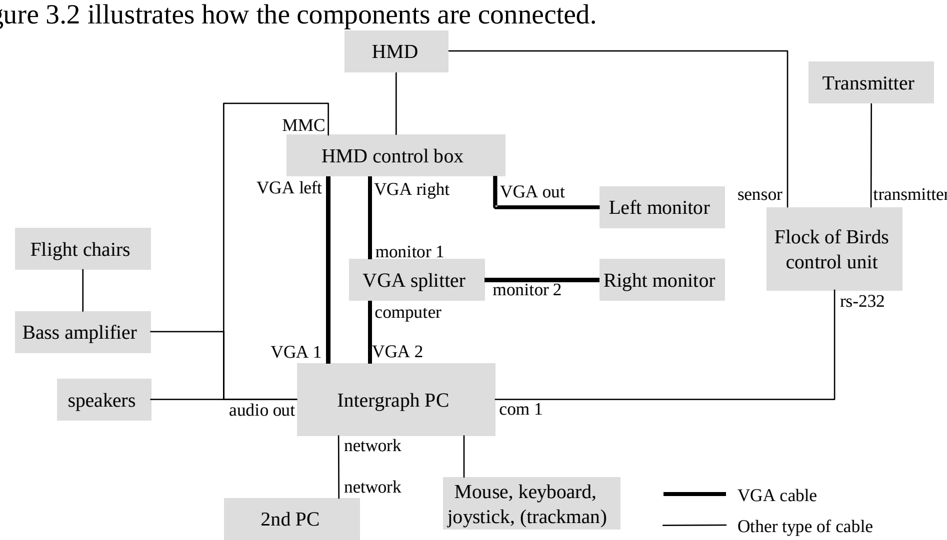

Fig 3.2 Overview of the components of the system and their connections (Schuemie, 2002)

3.1.2 Software Components

In order to write application and make Virtual Environment (VE) easier, high level library and tools are used instead of writing application by directly using the OpenGL or Direct3D API (Application Programmers Interface) (Schuemie, 2001).

Libraries

Libraries have lines of code, which can be activated with a single command. Commercial libraries are available such as World ToolKit from Sense8. However many researcher develop their own because it provide higher degree of flexibility, but it is very time consuming.

High level tools

The tools use a graphical user interface for making and developing the VE and its attributes. There are tools that offer complete packages, which comprise geometry modelling tool for the world and scripting language for dynamics behaviour of the VE, such as Superscape VRT and WorldUp from Sense8. However the flexibility of VE dynamic behaviour controlled by script language is limited. It cannot control and implement network communication and database access. Therefore some of the tools, such as WorldUp, allow calls to Dynamic Link Libraries (DLLs). These DLLs can be written in professional software development tools such Borland Delphi and Microsoft Visual Basic.

TU Delft use WorldUp as a high level toolkit for modelling, developing, and creating VE because WorldUp offer modelling tool and library for developing VE behaviour. WorldUp is also able to call DLLs for handling more complex behaviour such as network communication and graphical user interface for the therapist. The DLLs are developed by Delphi 5.

3.1.3 The Virtual Reality System

Both PC use Microsoft Windows operating system. The Intergraph PC uses Microsoft Windows NT and the second PC use Microsoft Windows 98. WorldUp R4 from Sense8, which is software tool used for creating VE is only installed in Intergraph PC because TU Delft only have one licence. WorldUp Player is installed in the second PC. The worlds that illustrate the VE are stored in the .up files and .wup files. Files in .up format is the editable version that can be opened and run from WorldUp. On the other hand, files in .wup format are non-editable, which can be run from WorldUp Player. Additional functionality is developed by Borland Delphi 5, which creates DLLs that can be called from WorldUp (Schuemie, 2002).

3.2 Environment Requirements

Here, I am going to list the requirements for the metro virtual environment, based on the hardware and software components mentioned earlier.

- The metro virtual environment should be built using WorldUp R4.
- The metro virtual environment must be able to run on the Intergraph PC with adequate frame rates that does not show lagging images to the user.
- The application should be written for a HMD with limited resolution.

4 Designing Environment

4.1 Users

There are two kinds of users that will use this VR application. They are the patients and the therapist. It is illustrated in the picture below. The user who is in the front of computer is the therapist while the user that wears the HMD is the patient.

Fig 4.1 VRET treatment, with the patient wearing a HMD

Fig 4.2 Therapist who controls the virtual environment

The patients are the passive user while the therapist plays more active roles. The patient uses the VE so that he can confront the feeling that he is afraid of. This feeling may be caused by several factors. For agoraphobia patient, the factor may come in the form of the feeling being trapped in the metro. Hence the metro virtual environment must be able to illustrate the feeling of confinement for the agoraphobia patients.

Therapist has dominant role because he is the one who controls and manipulates the factors that the patients afraid of. Therefore interaction of the virtual environment will be in the hand of the therapist.

It is difficult to determine the expertise of the users, since it can be various. The patients may come from different background. Therefore their literacy with the computer cannot be determined. Expertise of the patient is not so important because, as mentioned before, patient is the passive user. However, if the patients use the VR system for the first time, an introduction in the therapy session will be held.

The therapist may not be as experienced as the technical student with the computer. The therapist also may not have experience with VR system. The therapist, as the user who plays more interactive role, may have different expertise on computers. Therapists can be novice if they are new in VR technology. There can be an intermediate or expert therapist if he has worked using VRET for phobia treatment. The therapists that assist us on developing Rotterdam Metro virtual world come from the University of Amsterdam. They are already familiar with VRET. They also have treated some phobia cases with VRET. Therefore they can be considered as expert on the VR system.

With this analysis, the application should be easy enough to be used by users at any level of expertise. Because the level of computer knowledge for most of the users cannot be determined, all interactions in the application will be simple. In the following sections, the implementation of this process is considered carefully in all phases of designing.

4.2 Conceptual Design

It is important that the user understands how to use the system. Hence, a good foundation for designing a system is to determine how the user's ideas of how the system works. It is called user's mental models. By knowing the user's mental models, we can develop the design using the conceptual design techniques.

The therapist is the user who controls and actively interacts with the system. The therapist manipulates the virtual environment so that the patient can feel the stimuli that he fears of.

The virtual environment should give the patient the sensation in the metro. The virtual environment is modeled as close as possible to reality.

The patient sit in the virtual metro while it is moving and he will be able to feel that the virtual metro moves. The patient can move his head so that he can view his surrounding. The patient is also able to stand. However he cannot move and walk in the aisle and get out of the virtual metro. Sound will be added to enhance the realism factor of the virtual metro.

4.3 Semantic Design

Semantic design develops functional requirement of the system based on the analysis of what users should be able to do with the system. The explanation of the semantic design will be divided into two due to two types of user. First explanation based on the therapist side and second explanation based on the patient side. To get the feeling like in the real metro, the metro is modeled from Rotterdam Metro.

Functional requirement of the system will be based on the interview conducted with the therapist. The interview is focused on how the therapist treats agoraphobia patients. The therapist is also asked about the experience using VR to treat phobia patients and about the expectation with the metro virtual environment. The possible procedure of treating (agoraphobia) patients with VRET, in a nutshell, is as follow:

- The therapist asks the agoraphobia sufferers about their fear. Agoraphobia patients tend to have different kind of fear. In the public transportation (metro) cases, the fear relate to the real metro situation, such as trapped inside the metro. Hence the fear that is not related to the metro cases, such as fear of driving, will be disregard.

- The list of fear that relates to the metro situation is scaled. The usual scaling factor is from 0 to 100.
- Before the patients start the therapy for the first time, the therapist will give a brief introduction about the VR system and will show the therapist the neutral VE.
- The therapy consists of several sessions. The amount of sessions depends on each patient. Each therapy session gives tasks to the patients. The task will give the patients some practice in handling and overcoming their fear and anxiety. Tasks in the earlier session will be easier than the later tasks because the task will be based on scale of list that was compiled by the therapist based on the interview with the patients.

To help the therapist accomplish his mission, the metro virtual environment has to be able to show the patients the situations that they fear of.

The patients are the passive user. The virtual environment does not give patient the idea that he is in control of the environment. They expect to get some exposure to the situation, which give them anxiety. Situations that will create anxiety to the agoraphobia patients must be featured in the metro virtual environment application. These situations are as follow:

- Patients should be able to feel the illusion that they sit inside the metro.
- Patients should be able to feel the illusion of taking a journey with virtual metro.
- Patients should be able to feel the presence of crowd in the metro.

Therapist is the active user who controls the metro virtual environment. To control the metro virtual metro, the application has to be able to:

- Establish connection between intergraph computer that render the virtual world and the second computer where the user interface is.
- Show the connection status between intergraph computer that render the virtual world and the second computer where the user interface is.
- Show the patient's viewpoint. It means that the therapist is able to see what the patients see inside the metro virtual environment.
- Show the free viewpoint. It means that the therapist is able to see patient's position inside the metro virtual environment.

4.4 Syntactical Design

In designing this application, again we start with the user's mental model. There are four general modes of mental model from users of interactive system (Shneiderman, 1998). They are:

- State transition model. It is a model that is used if the system can switch between different forms of behavior.
- Object-action model. It is a model from the concept about object accessible via the user interface and the actions they can perform on these objects.
- Mapping model. It is a model that is used in system with repetitive sequences of actions.
- Analogical models. It is a model that arises when users comes across a new system that similar with a system they are familiar with.

To design the metro world, the state transition model will be used.

The metro virtual environment is simple. The virtual environment will show the virtual journey by metro so that the patients can feel that they are in the metro. The state of the metro is shown it the figure 4.3. The state transition diagram describes the different states the control can be in.

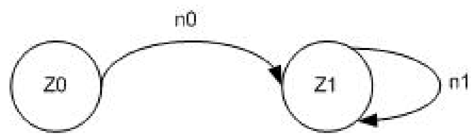

Fig 4.3 Metro controls STD

Z0	Metro stills
Z1	Metro moves through the tunnel
n0	Connection between two computers is established
n1	End of the tunnel is reached by the metro

4.5 Lexical Design

This section will describe the Metro virtual environment, which is called Metro Version 1. The metro is modelled after the metro in Rotterdam. The inside is built as similar as possible with Rotterdam Metro. Figure 4.4 illustrates the real interior of Rotterdam Metro.

Fig 4.4 Rotterdam Metro (Courtesy of Fitri N.Rahayu)

These following pictures show the Rotterdam metro virtual world that has been developed. Figure 4.5 shows how the virtual metro is built similar with the real Rotterdam metro. The patient will be located on of the seats in the right side. Hence the patient will view the virtual world from his location as if he sits inside the metro as a regular passenger. Although the patient can stand up, he cannot walk in the aisle and change seat because the location of the patients is programmed on a certain bounded position.

Fig 4.5 Metro virtual environment version 1

In order to illustrate crowd, some virtual people must be added in the metro. Because of difficulty in developing dynamic and pure 3D virtual people, the static virtual people, which is simpler to create, are added to get the crowd impression. Example of the static virtual people can be seen in the figure 4.6.

Fig 4.6 Metro virtual environment version 1with crowd

The virtual people avatars mostly stand still on their location. They can only move a little when the patient changes his viewpoint by moving his head. The avatars are 2D objects that can rotate based on the patient viewpoint. This rotation gives impression of little movement.

The static avatars are not realistic enough, compare to the dynamic avatars. This is the disadvantage of using static avatars. There is a concern that unrealistic avatars may influence the patients negatively when in virtual worlds. Therefore, in the evaluation or experiment stages where presence in the metro virtual environment is tested, comparison between empty metro and crowded metro with static virtual avatars will be conducted.

In order to get the impression of moving, the patient will sit on the chair that is connected with the speaker. The speaker will create vibration, which will give the patient an illusion of moving metro.

Since the metro moved in the tunnel, a texture is created to illustrate the tunnel. This tunnel texture is illustrated in figure 4.7 below.

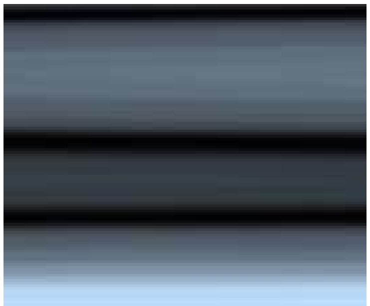

Fig 4.7 The tunnel texture version 1

In order to control the metro virtual environment, user interface must be created. Simple user interface is created. The UI is based on the UI that has been developed earlier. It is a simpler version of UI. The figure 4.8 below illustrates the UI. The UI consists of connection status located on top left of the image, patient viewpoint located on top right of the image, and free viewpoint located on bottom right of the image.

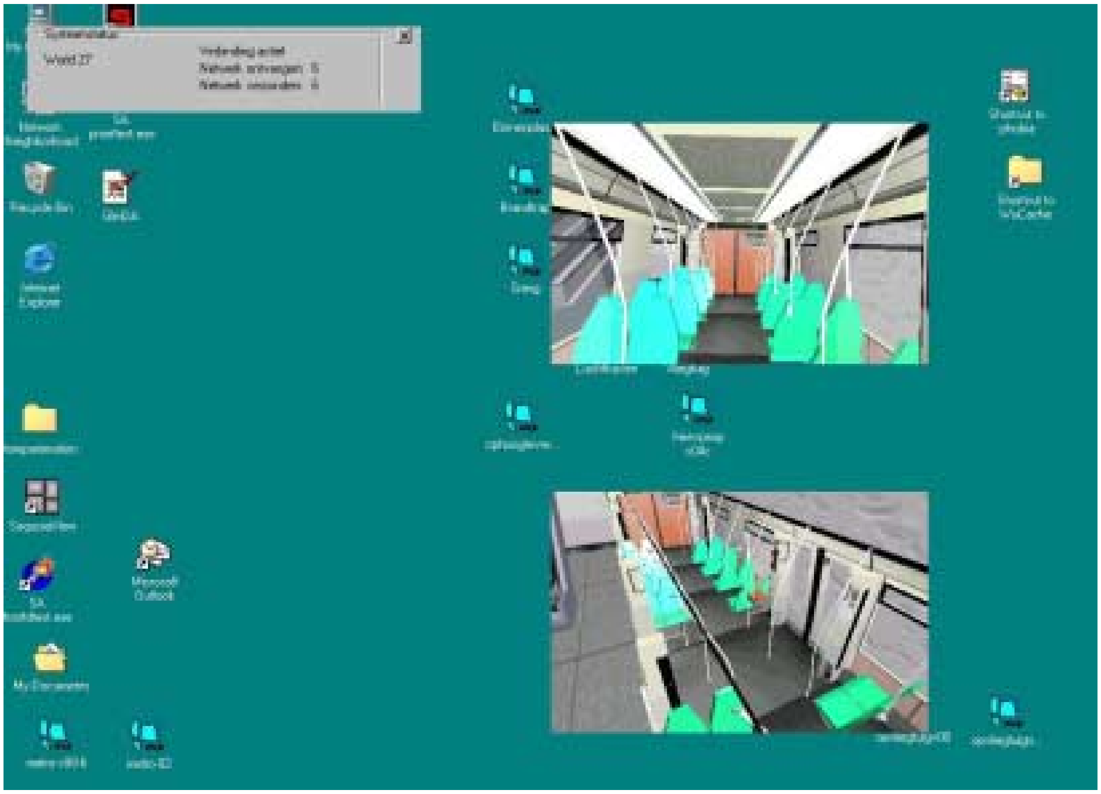

Fig 4.8 The simple UI for the therapist version 1

4.6 Iteration in prototyping

4.6.1 First Prototype (Version 1)

The first model of the metro was a simple model of the metro. The metro could move through the tunnel. There are some people inside the metro. This model is tested to the therapist.

Based on the therapist response and input, this Metro Version 1 needs improvement because it doesn't have good interactivity to the therapist. As mentioned in the semantic design section, the patients may have lists of situation that they are afraid of. Each of the situations has different weight scale. For example, a patient may less afraid in the empty metro than in the crowded metro. Better control to the therapist in order to manipulate the situation in the metro will enhance the metro VE application.

In order to enhance Metro Version 1, these following features should be improved:

- The tunnel texture. In some parts of the tunnel, when metro moves, the user cannot feel the movement because the user cannot see the changes in the tunnel texture.
- The virtual people. The virtual people must be added to give the illusion of crowded metro.
- User interface that give more control to the therapist.

In order to enhance the Metro Version 1, the therapist also ask to add these following features:

- Metro station in the virtual environment.
- Sound of people to give illustration of crowded metro.

4.6.2 Evaluating First Prototype (Version 1)

Based on the therapist input, some ideas to develop better world for agoraphobia VRET is acquired. There are some changes in the semantic design and syntactical design.

4.6.2.1 Changes to semantic design

Then therapist can do different kinds of exposure to the patients. Based on the interview with the therapist, these following scenario for the metro VE is acquired:

- The therapist controls the movement of the virtual metro. He can stop the metro in the station. He can also stop the metro in the tunnel. Manipulating the movement of the metro can be used to manipulate the agoraphobia sufferer anxiety.
- The therapist moves the position of the patient. Location of the patient is important because agoraphobia sufferer is more comfortable in the seat near the door. Therefore changing location can be used to manipulate the patient's anxiety.
- The therapist changes the amount of the virtual people in the virtual metro. As mentioned before, from the therapist input, anxiety generated by empty metro and crowded metro is different because agoraphobic is more afraid of the crowded metro than the empty metro. Hence changing the amount of the virtual people also may be used to manipulate the patient's anxiety.
- The therapist turns off the light. There is a possibility that turn the light off may increase the patient's anxiety.

Based on the therapist input, there are some additional changes to the metro virtual world. In the virtual environment, these following features are added:

- The patient is able to feel the illusion of metro stop moving when it stands still in the dark tunnel.
- The patient is able to feel the metro stops in the station.

Because the metro virtual environment version 1 has little control and interactivity, the therapist cannot manipulate events in the virtual environment. In order to control the metro virtual environment and to add more situations that patients fear of, user interface must be created. Simple user interface is created. It is a simpler version of UI that has been developed (Schuemie,2003). The user interface has these following features:

- The therapist is able to control the number of virtual people in the metro.
- The therapist is able to choose the seat for the patient in the metro. There are two kinds of seats position. The seats near the door and the seats far from the door.
- The therapist is able to control the light
- The therapist is able to control metro movement.
- The therapist is able to stop the metro movement in the dark tunnel.
- The therapist can calibrate the viewpoint of the patient in the metro.

4.6.2.2 Changes to syntactical design

The syntactical design of the metro is simple. The therapist, as the user, could only control these following features:

1. Patient's seat.
2. Number of avatars or virtual people.

3. Light
4. Metro movement

The various states the metro could be in will be described below. They are as follow:

Patient's Seat

Only therapist can control the patient's seat. The selection of the seat consists of two seats near the door and two seats far from the door. The therapist can choose the seat for the patient before the metro moves or during the metro moves. The state transition diagram (STD) illustrated in figure 4.9 describes the different states the control can be in.

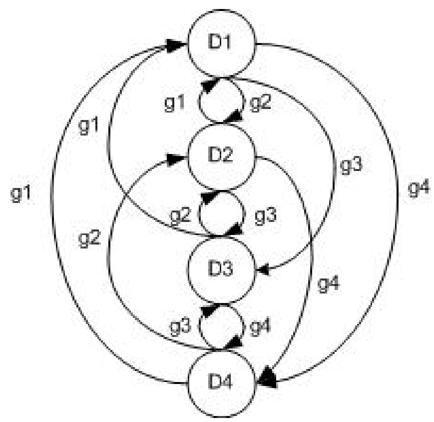

Fig 4.9 Patient's Seat Controls STD

D1	Patient located in the position 1
D2	Patient located in the position 2
D3	Patient located in the position 3
D4	Patient located in the position 4
g1	Position 1 button is pressed
g2	Position 2 button is pressed
g3	Position 3 button is pressed
g4	Position 4 button is pressed

Number of Avatars or Virtual People

Only therapist can change the numbers of avatar in the metro. There are three choices of metro density, which consist of no avatars, few avatars, and many avatars. The therapist can choose the number of avatars while metro stops or metro moves. The state transition diagram illustrated in figure 4.10 describes the different states the control can be in.

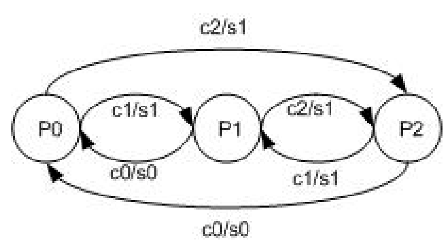

Fig 4.10 Number of Avatars Controls STD

P0	No people in the metro

P1	Few people in the metro
P2	Many people in the metro
c0	No people button is clicked
c1	Few people button is clicked
c2	Many people button is clicked
s0	Sound of crowded metro is off
s1	Sound of crowded metro is on

Light

Only therapist can control the light in the metro. Therapist can choose whether the light is on or the light is off. The state transition diagram illustrated in figure 4.11 describes the different states the control can be in.

Fig 4.11 Light Controls STD

L1	The light is on
L2	The light is off
n0	Light off button is clicked
n1	Light on button is clicked

Metro movement

Therapist can change the status on the metro. Based on the therapist preferences, the metro can move through the tunnel and station, stop in the station, and stands still in the tunnel. The state transition diagram illustrated in figure 4.12 describes the different states the control can be in.

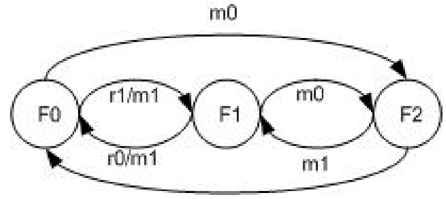

Fig 4.12 Metro controls STD

F0	Metro stops in the station
F1	Metro moves through tunnel and station
F2	Metro stands still in the tunnel
r0	Metro stops button is clicked
r1	Metro moves button is clicked
m0	Metro stands still button is not clicked
m1	Metro stands still button is clicked

4.6.2.3 Changes to Lexical Design

More virtual people are added in order to make metro looks more crowded. It is illustrated in the figure 4.13 and 4.14. Virtual people added are the same type with the virtual metro in Metro Version 1. It is static virtual people. Although they are static virtual people or avatars, which are easier to render than the dynamic avatars, I cannot add more than ten avatars to the metro. When more than ten avatars were added to the metro, the frame rate of virtual environment drop until the frame rates reached 4 frames per second (fps). The decrease of the frame rate is very significant since the patient receives lagging images when he is in the virtual environment. Hence the new version of metro VE (Metro Version 2) does not contain more than 10 static virtual people.

Fig 4.13 Inside the crowded metro version 2

Fig 4.14 Inside the crowded metro version 2

Station is added to give more realistic impression of virtual journey with the metro. The station is developed based on Blaak station in the Rotterdam. It is similar although it is not identical with the Blaak station. The station is illustrated in the figure 4.15 and 4.16 below. The design does not pay attention to the detail of the station due to prevent the problem in rendering. Hence some detail in the station, such as bin, seat, and people are being ignored. More detail and complex world will add the burden to the Intergraph computer. Example of this problem occurred when I tried to add more than ten avatars.

Fig 4.15 Station viewed from inside the metro version 2

Fig 4.16 Metro Station with Elevator version 2

As mentioned before, the tunnel texture should be changed. New texture of the tunnel so that the patient can feel the illusion of the movement to virtual metro can be seen in the figure 4.17.

Fig 4.17 The Tunnel Texture version 2

To give more control to the therapist, the therapist's user interface is improved. The new simple UI for the therapist is illustrated in the figure 4.18. The user interface is designed based on the changes in the syntactical design. As mentioned in the syntactical design, there must button to control the virtual behavior. There are four kinds of control. They are people control, seat control, light control, and simulation control. The location of connection status that shows the connection information between Intergraph pc and 2nd PC is changed. It is on the bottom left of the UI.

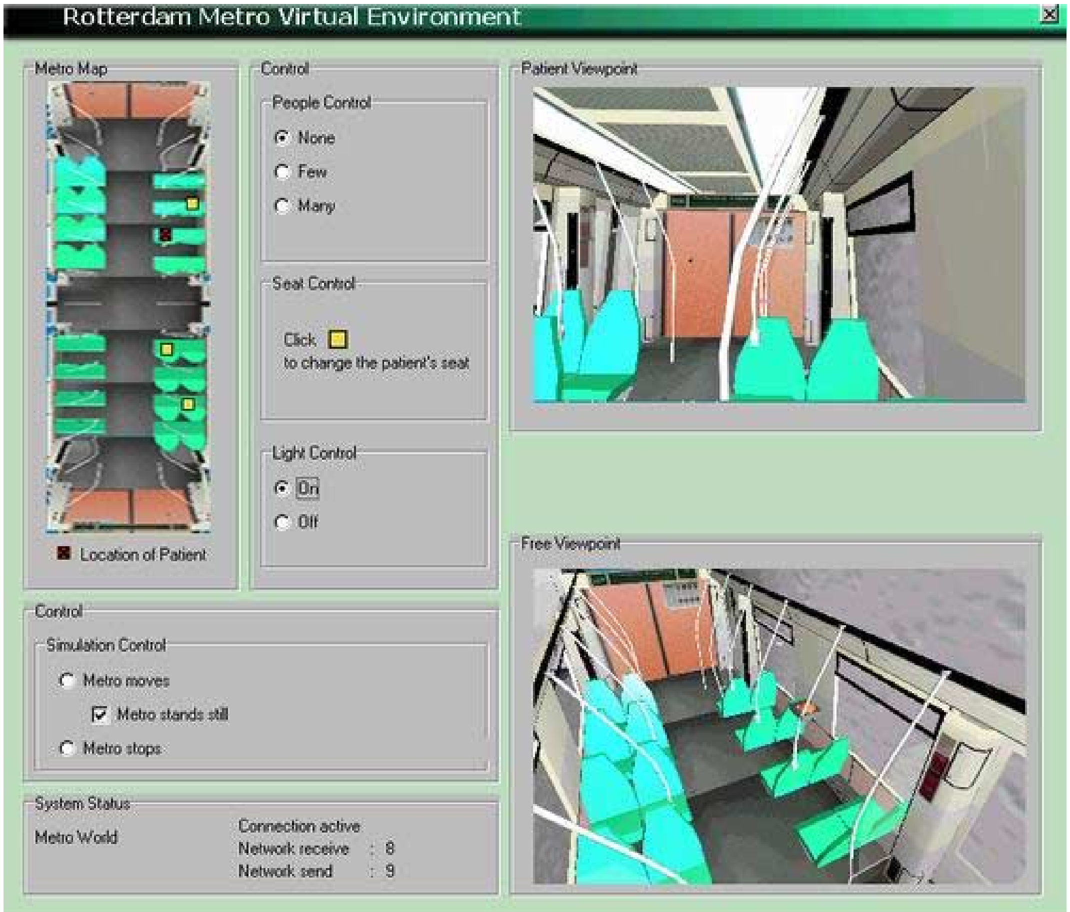

Fig 4.18 Simple UI for the therapist version 2

4.6.3 Evaluating Second Prototype (Version 2)

Based on the therapist input, some ideas to develop better world for agoraphobia VRET is acquired. There is one minor change applied in the lexical design.

4.6.3.1 Changes to Lexical Design

The therapist needs to calibrate the patient viewpoint before show the patient the metro virtual environment. Instead providing button in the UI, the calibration is done by clicking the joystick.

The UI is slightly changed because the therapist has problem in the simulation control section. The information that explains the function of the button is ambiguous. 'Metro stops' button and 'Metro stand still' button has the same meaning. Hence simulation section is modified as illustrated in figure 4.19. The modifications applied to the information of the button functionality on the therapist's UI version 2 are as follow:

- 'Metro stops' button is changed into 'metro stops in the station' button.
- 'Metro stands still' button is changed into 'metro stands still (in the tunnel)' button.
- 'Metro moves' button is changed into 'metro moves (through the tunnel and station)' button

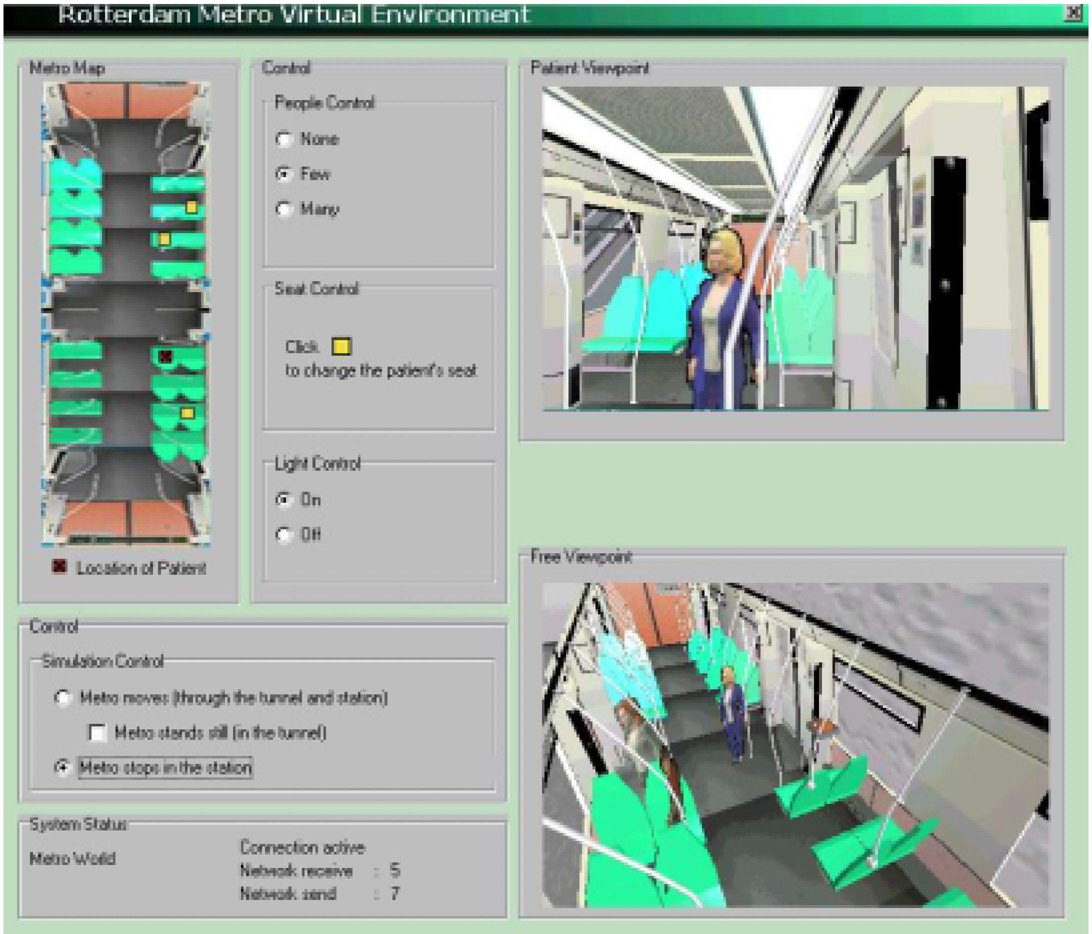

Fig 4.19 Simple UI for the therapist version 3

5 The Experiment

This chapter will explain the experiments, which were done using the metro virtual environments described in the earlier chapter. The first section will give a description of the experiments setup. The second section will illustrate the subject and the experiment. The final section will cover the result of the experiment and its conclusion.

5.1 Setup used for experiments

The place where testing was done is in the room with privacy. There are two computers, three monitors. The first computer (Intergraph PC) is responsible for rendering the images. Monitor 1 shows the patient's viewpoint from the left eye and monitor 2 shows the patient's viewpoint from the right eye. The therapist controls the metro virtual world from the 2nd computer.

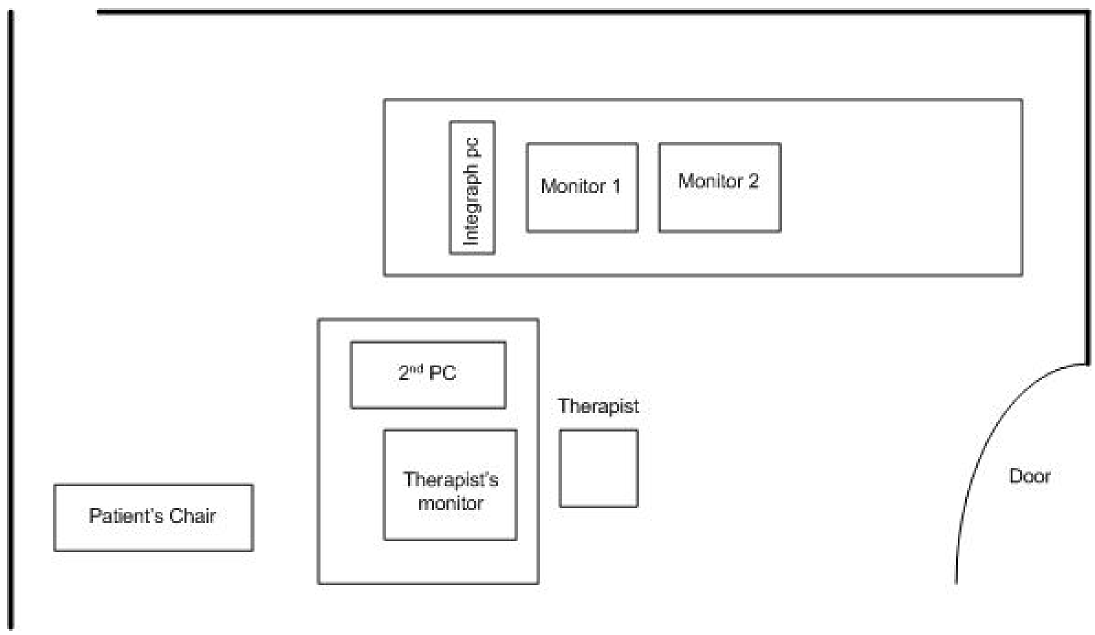

Fig 5.1 Setup of experiment

The subject sits on the patient chair wearing the HMD while in the virtual metro. Subject can view the metro virtual environment and hear sound of the people in the virtual metro and salso ound of moving metro from the HMD. The chair that is used in the experiment is an airplane seat. Actually this chair is used for fear of flying VRET. The chair has a speaker attached to it. The speaker is used and needed to create the vibration in the chair. The vibration in the chair is required for giving the illusion of moving metro to the subject who sits on the chair. Hence the airplane seat is used instead of using real metro seat.

5.2 Presence Experiment

The experiment was started from 21st July 2003 and lasted until 25th July 2003. The experiment was conducted to test the presence experience that is produced by the pilot metro VE. The VE were shown to twenty volunteers who acted as subjects. All volunteers were students of TU Delft and they do not suffer from agoraphobia. The following section will describe how the experiment is conducted and its result.

As mentioned before, the experiment purpose is to test the presence experience generated by the metro VE. The experiment procedure is as follow. Before the experiment, brief introduction was given to the subjects. Basically, the introduction explained subjects briefly about the VR equipment and also told the subjects about the exposure to the metro VE. The metro VE exposure was done twice. First, the subjects were shown the empty metro VE through the HMD then they were given questionnaires to measure their sense of presence. After they finished filling the questionnaires, the subjects were shown again with the metro VE through the HMD. However, the second VE shown to the subjects is the metro VE with virtual people. After the subjects finished, they were given the same questionnaires. Each of VE exposure takes about 7 minutes.

5.3 Measurement

Questionnaire that is given to the subjects after they experience metro virtual world is IPQ. Igroup Presence Questionnaires (IPQ) differentiates presence and immersion. Sense of presence is used as a variable of a user's experience in the virtual environment. The current version of the IPQ has three subscales and one general item not belonging to a subscale. Those three subscales are (Schubert, 2003):

1. Spatial Presence: the sense of being physically present in the VE
2. Involvement: measuring the attention devoted to the VE and the involvement experience in the VE
3. Experienced Realism: measuring the subjective experience of realism in the VE.

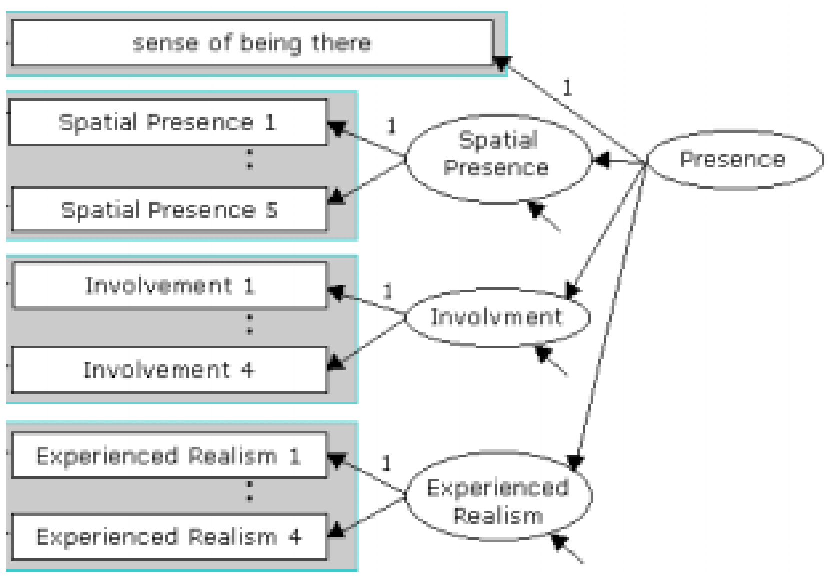

Fig 5.2 Presence scale developed by structural equation modelling
(courtesy of http://www.igroup.org/pq/ipq/)

There is also a general item that measures the general "sense of being there". IPQ has 14 items, which consist of one general item, five spatial presence items, four involvement items, and four experienced realism items. Each items is assessed with rating scale from 0 to 6. The figure 5.2 illustrates how these items in the IPQ relate to the presence measurement.

5.4 Result

5.4.1 Reliability

A reliability analysis for the questionnaires is performed. The results are displayed in the table 1. Cronbach's alpha model is used to measure the reliability. This is a model of internal consistency, based on the average inter-item correlation.

Table I

Measure	*N of cases*	*N of items*	*Alpha*
IPQ session 1	20	14	.4909
IPQ session 2	20	14	.5494

5.4.2 Presence

The average questionnaires result is shown in the table II below.

Table II

	Mean	*Standard Deviation*
SP session 1	3.56	0.796307
SP session 2	3.75	0.664514
INV session 1	2.6375	0.635957
INV session 2	2.8375	0.722181
Real session 1	2.7	0.541684
Real session 2	2.7125	0.629719
G session 1	3.7	0.864505
G session 2	3.95	0.759155

The result of the questionnaires will be illustrated in the boxplot graphs. The boxplot includes these following information: median, quartiles and extreme values. Median is represented by a line across the box. The box represents the interquartile range that contains the 50% of values. The extreme values are represented by the whiskers. The whiskers are lines that extend from the box to the highest and lowest values.

The figure 5.3 shows the Spatial Presence (SP) from the questionnaire result. It can be seen that both session yields similar result. However the first session yields the highest SP scale although the interquartile range and the median for second session SP is higher than the first session SP.

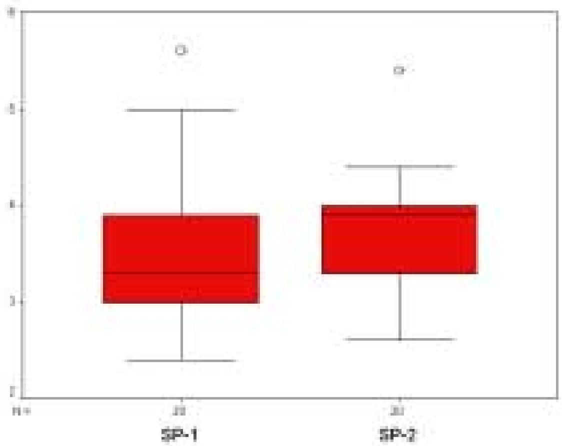

Fig 5.3 Spatial Presence result

The figure 5.4 shows the ‘sense of being there’ from the questionnaire result. It can be seen that both session yields similar result. However the second session yields the higher interquartile range than the first session. This result can be caused by the static avatars because some people may perceive them as unrealistic. Hence some subject may feel higher sense of being in the empty metro than in the crowded metro.

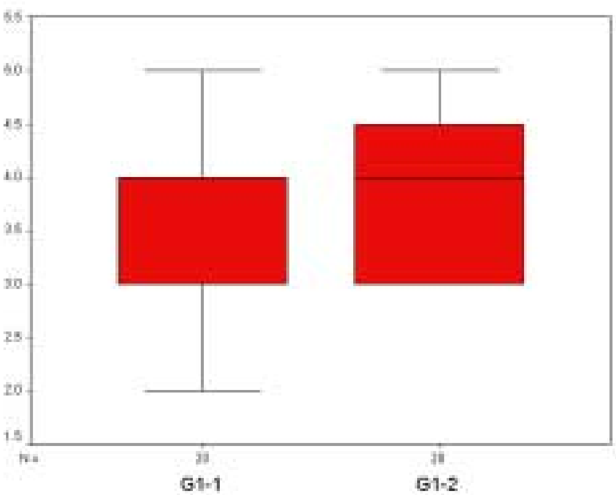

Fig 5.4 Sense of being there result

The figure 5.5 shows the Involvement (INV), which is used to measure the attention devoted to the VE, from the questionnaire result. It can be seen that both session yields similar result although the second session yield the highest INV scale. The interquartile range INV result scores lower than the SP result.

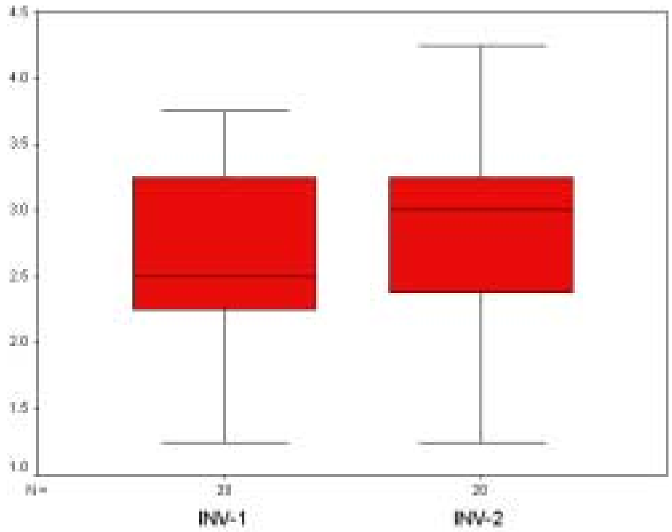

Fig 5.5 INV Result

The figure 5.6 shows the Experienced Realism (REAL), which is used to measure the subjective experience realism in the VE, from the questionnaire result. It can be seen that both session yields similar result. The interquartile range REAL result scores lower than the SP result.

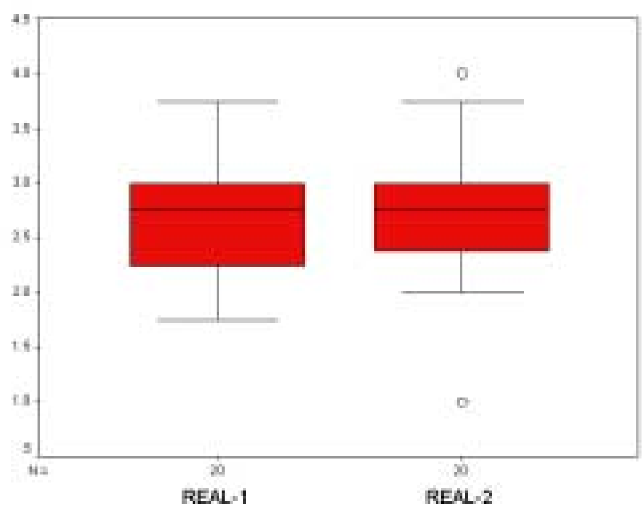

Fig 5.6 REAL result

5.5 Conclusions

As mentioned in the earlier chapter, the lack of presence is the main reason that VRET fail (Schuemie, 2003). From the presence experiment that has been conducted, the experiment shows that the metro with virtual people and empty metro get almost similar score, although metro with virtual people tends to get higher result. But the difference between score from metro VE and from crowded metro is small. Hence the static virtual people that look unrealistic compare to the 3D dynamic virtual people does not affect the result negatively.

The REAL (item that measures the realism in the VE) and INV (item that measures the attention and involvement experience) score less than the SP (item that measures sense of being physically present in the VE) and G (item that measures general sense of being there). It means that the metro virtual environment is able to give the illusion to the subjects that they are in the metro instead of in the lab but the subjects still feel that the virtual metro is not the same with the real metro because the virtual metro is not real enough and the subjects is too passive (they cannot walk in the aisle for example.

Lots of subjects complain about the HMD, such as:

- The HMD was too heavy.
- The HMD made them uncomfortable.

These factors also may contribute to the REAL item result.

6 Conclusions and Recommendations

6.1 Conclusions

The project, which is designing a prototype Rotterdam metro virtual environment, has been realized and the goal, as written in the first chapter of this report, has been fulfilled. The first of this section will give an overview about designing the environment and the next section will look at what was learned about presence experience in the Rotterdam metro virtual environment.

The pilot design has met some of the requirements mentioned in the chapter 3:

1. The metro virtual environment is developed using WorldUp R4 software. Although WorldUp R4 software has lots of advantages as mentioned in the chapter 3, there is a disadvantages regarding to the geometry model development. The complex geometry model cannot be implemented in the virtual environment because modeler provided by WorldUp R4 software, which is used to create the geometry model and to attach texture in order to add realism in geometry model, is too simple. The modeler is designed to create basic geometry model. Making or attaching texture to the complex geometry model is very hard. Hence creating very realistic and 3D virtual people will take a lot of time because human body is very complex to model. Therefore 3D dynamic virtual people or avatars are not implemented in the metro virtual world. The 3D dynamic virtual people or avatars are replaced with the static virtual people instead.

2. The metro virtual environment is able to run in the Intergraph PC with adequate frame rates. The subjects from the experiment never complained about the lagging images. Integraph PC is PC with Pentium 2 450Mhz processor. Therefore the metro VE cannot contain lots of polygon. Most of the VE that has been developed in this VR system use approximately 790 to 2000 polygons. The VE must not use more than 2000 polygons because using more that 2000 polygons may yield unexpected result in the rendering process. Because of this restriction, the pilot metro VE developed in this thesis project is not a big and a complex virtual world.

3. The metro virtual environment can be viewed by the HMD with 640x480 resolution. Because of the limited resolution, the quality of the texture in the metro VE cannot be enhanced anymore in order to create more realism in the metro VE.

On the result of presence experiment to test the metro VE these following conclusions are taken:

- The experiment shows that the metro with virtual people and empty metro get almost similar score, although metro with virtual people tends to get higher result. But the difference between score from metro VE and from crowded metro is small. Hence the static virtual people that look unrealistic compare to the 3D dynamic virtual people does not affect the result negatively.
- The Involvement item, which measure attention devoted to the VE, score less than the Spatial Presence item. It may be caused by the lack of interactivity in the metro VE because the user in the VE is very passive.
- The Real item, which measure the subjective experience of realism in the VE, also score less than the Spatial Presence item. It may be caused by the simplicity of the metro VE and also by the unrealistic static virtual people.

6.2 Recommendations and Future Research

In the future, the pilot metro virtual environment can be improved by adding these following features:

- More stations.
- Dynamic virtual people.
- More interactivity to the patient, such ad the ability of the patient to move freely in aisle and to go out of the metro.
- Better quality sound.
- Better vibration of the chair.
- The ability to prolong the metro in the tunnel.

The simple therapist's user interface can be improved by adding features that is needed by the therapist based on the research conducted by Schuemie (Schuemie,2003), such as:

- Subjective Units of Discomfort (SUDs) recording.
- Information of the patient that contains name and session number.
- Time Information
- Better control and interactivity in the free viewpoint that shows position of the patient in the VE.

To find out more about presence experience produced by Rotterdam Metro VE, more research has to be done. More subjects must be included to get better reliability result.

To find out whether this metro virtual environment can treat the agoraphobia patients, another experiments with agoraphobia patients must be conducted. The experiment that must be done is to test how good VRET using Rotterdam Metro VE is, compared to in vivo. Unlike doing the presence experiment, to test the metro VE to the agoraphobia patients, the therapist must involve in the bigger role

References

Bryson, S. (Retrieved: 4th February 2003) *Virtual Reality: A Definition History, Lexicon Definition Supplement*. http://www.fourthwavegroup.com/fwg/lexicon/1725w1.htm

Cognitive Behavior Therapy, (Retrieved: 1st March 2003), homepage: http://www.cognitive-behavior-therapy.org

Emmelkamp, P.M.G., Krijn, M., Hulsbosch, L., de Vries, S., Schuemie, M.J., van der Mast, C.A.P.G (2002) Virtual Reality Treatment versus exposure in vivo: A Comparative Evaluation in Acrophobia, *Behaviour Research & Therapy*. Vol.40, No.5, May, pp. 509-516

Harrison, David J., Jaques, Mark W.S. (1996) *Experiments in Virtual Reality*, Butterworth – Heinemann, Scotprint Ltd, Musselburgh, Great Britain.

Hodges, L., Rothbaum, B.O, Kooper,R., Opdyke, D., Meyer, T., de Graaf, J.J., Williford, J.S. (1994) Presence as the defining factor in a VR application, Georgia Institute of Technology

Isdale, J., (1998) *What is Virtual Reality, http://vr.isdale.com/WhatIsVR.html*

Kooper, R., (1994) *Virtually Present: Treatment of Acrophobia by Using Virtual Reality Graded Exposure,* Master Thesis, TU Delft

Lombard, M. *Resources for the study of presence: Presence explication,* (Retrieved June 2003), homepage: http://nimbus.temple.edu/~mlombard/Presence/explicat.htm

National Institute of Mental Health (NIMH), (Retrieved: 1st March 2003), homepage: http://nimh.nih.gov

Psychology Today, (Retrieved: 1st March 2003), homepage: http://www.psychologytoday.com/

Rahayu, F.N., (2003) *Virtual Reality for Social Phobia and Agoraphobia Treatment,* Research Assignment Report, TU Delft

Tromp, J.G., Fraser, M.C., (1998) *Designing Flow of Interaction for Virtual Environments,* http://www.mrl.nottingham.ac.uk/~mcf/publications/ueve/ueve98.html

Schloerb, D.W. (1995) *A quantitative measure of telepresence, Presence,* Vol 4, pp 64-80

Schubert, T.W., Friedman, F., Regenbrecht, H.T., (Retrieved July 2003) *The Experience of Presence: Factor Analytic Insight,* homepage: http://www.igroup.org/pq/ipq/

Schuemie, M.J. (2003) *Human-Computer Interaction and Presence in Virtual Reality Exposure Therapy*, Ph-D dissertation, Delft University Press

Schuemie, M.J. (2002) *Phobias and Virtual Reality: System Manual,* Internal Report TU Delft

Schuemie, M.J, van der Straaten, P., Krijn, M, van der Mast, C.A.P.G. (2001) *Research on Presence in Virtual Reality: A Survey*, Cyber Psychology & Behavior, Volume 4, Number 2, Mary Ann Liebert, Inc, pp 183-202

Schuemie, M.J., and van der Mast, C.A.P.G., (2001) *VR Testbed Configuration for Phobia Treatment Research*, M.E. Domingon, J.C.G. Cebollada & C.P. Salvador (Eds.), Proceedings of the Euromedia 2001 Conference, Valencia, Spain, pp. 200-204

Shneiderman, Ben. (1998) *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, Addison Wesley Longman

Slater, M., Steed, A., Usoh, M. (1993) The Virtual Treadmill: A Naturalistic Metaphor for Navigation in Immersive Virtual Envorinments, M. Goebel (ed), *First Eurographics Workshop on Virtual Reality*, pp. 71-86

Slater, M. Wilbur, S. (1997) *A Framework for Immersive Virtual Environment (FIVE): Speculations on the Role of Presence in Virtual Environments*, *Presence*, Vol 6. No 6., pp 603-616

Social Phobia/Social Anxiety Association, (Retrieved: 1st March 2003) homepage: http://www.socialphobia.org

Vince, J., (1998) *Essential Virtual Reality Fast: How to Understand the Techniques and Potential of Virtual Reality*, Springer-Verlag, London, UK

Virtual Reality Medical Center (VRMC), (Retrieved: 1st March 2003), homepage http://www.vrphobia.com

Witmer, B.G., Singer, M.J. (1998) *Measuring Presence In Virtual Environments: A Presence Questionnaire*, *Presence*, Vol 7, No 3, pp 225-240

Appendix A: Protocol for the interviews of therapist

Introduction

Explain course of interview
‘The goal of interview is to gain insight into the possibility way of performing agoraphobia treatment and any wishes and requirement for a future VR-system’
The interview will last approximately 10 to 15 minutes’

Informed consent
‘Any information you will provide during the interview will be treated confidentially and will not be linked to your name.

General information
‘First, I would like to ask you whether you have treated patients using VRET.’

‘For the remainder of the interview, I would like you to consider the questions with relation to the agoraphobia treatment using VRET.’

Goal tree and implementation
‘I would like to ask you to tell me the steps that such a treatment consist of. Because the treatment will use Metro virtual environment, what does a treatment look like? Please start from the moment a patient starts VRET treatment for the first time.

The course of this part of the interview can be controlled with the following questions:
‘Why?’, ‘With which purpose?” to determine any higher-level goals and ‘How?’ to determine lower level goals and implementation detail.
‘When will you do that?’ to determine the information used by the therapist for specific steps.

Complaints and wishes
‘Furthermore I would like to ask you if there are any obstacles in your current way of working, and possibly any wishes and requirement for a future VR-system.’
‘What is currently often something that goes wrong?’
‘What takes up most of your time?’
‘Can you think of any wishes you might gave for a VR system?’

Finish
‘That’s it. Thank you very much for your cooperation’.

Appendix B: Igroup Presence Questionnaire (IPQ)

IPQ

Age:

Gender:

1. In the computer generated world I had a sense of "being there"

Not at all						Very much
0	1	2	3	4	5	6

2. Somehow I felt that the virtual world surrounded me.

Fully disagree						Fully agree
0	1	2	3	4	5	6

3. I felt like I was just perceiving pictures.

Fully disagree						Fully agree
0	1	2	3	4	5	6

4. I did not feel present in the virtual space.

Did not feel						Felt Present
0	1	2	3	4	5	6

5. I had a sense of acting in the virtual space, rather than operating something from outside.

Fully disagree						Fully agree
0	1	2	3	4	5	6

6. I felt present in the virtual space

Fully disagree						Fully agree
0	1	2	3	4	5	6

7. How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?

Extremely Aware			Moderately aware		Not aware at all	
0	1	2	3	4	5	6

8. I was not aware of my real environment

Fully disagree						Fully agree
0	1	2	3	4	5	6

9. I still paid attention to the real environment.

Fully disagree Fully agree

0 1 2 3 4 5 6

10. I was completely captivated by the virtual world.

Fully disagree Fully agree
0 1 2 3 4 5 6

11. How real did the virtual world seem to you?

Completely real Not real at all
0 1 2 3 4 5 6

12. How much did your experience in the virtual environment seem consistent with your real world experience ?

Not consistent Moderately consistent Very consistent
0 1 2 3 4 5 6

13. How real did the virtual world seem to you?

about as real as an imagined world indistinguishable from the real world

0 1 2 3 4 5 6

14. The virtual world seemed more realistic than the real world.

Fully disagree Fully agree
0 1 2 3 4 5 6

Appendix C: Metro Environment Script

MStartup

```
declare sub InitClient stdcall lib "c:\DLLs\PhobiaClient.dll"
declare sub InitServer stdcall lib "c:\DLLs\SimpleServer.dll" (ByVal L&)
global E1!, E2!, E3!, E4!, E5!, E6!, E7!, E8!, E9!, E10!
global ThisCompu$

function Retrieve (param as string) as string
  dim s as string
  dim l as string
  open "c:\Phobia.ini" for input as #1
  Do While (Not EOF(1)) and (not (l = param))
    Line Input #1,s
    l = left (s, len(param))
  Loop
  Retrieve = right (s, len(s)-len(param)-3)
  close #1
end function

sub main( )
  dim human as movable
  dim scr as Window
  dim vp as viewpoint
  E1! = 0
  E2! = 0
  E3! = 20
  E4! = 0
  E5! = 0
  E6! = 0
  E7! = 0
  E8! = 0
  E9! = 0
  E10! = 0

  ThisCompu$ = Retrieve("ThisCompu")
  Message (ThisCompu$)
  Select Case ThisCompu$
    Case "VRstation"
      InitClient                                        'Start the client dll
      set human = getMovable ("humanclient")
            human.enabled = true                        'enable client scripts
      set human = getMovable ("humanserver")
            human.enabled = false                       'disable server scripts

      set human = getMovable ("head")
            human.enabled = false                       'disable head

            set scr = getWindow ("Fullscreen-LeftEye")
      set vp = getViewpoint ("LeftEye")
            set scr.Viewpoint = vp
      scr.LeftEdge = 0
            scr.Width = 640
            scr.Height = 480
            scr.TopEdge = 0
            scr.YonClipping = 5e+025

            set scr = getWindow ("Fullscreen-RightEye")
      set vp = getViewpoint ("RightEye")
            set scr.Viewpoint = vp
      scr.LeftEdge = 640
            scr.Width = 640
            scr.Height = 480
            scr.TopEdge = 0
```

```
        scr.YonClipping = 5e+025

    dim B1 as new Bird
    B1.Sensitivity = 95
    B1.serialbaudrate = 115200
    B1.unit = 1

    dim success as boolean
    success = B1.Construct ("Bird-1")                   'create bird-1

    dim M1 as new MotionLink
    dim Source as vbase
    dim Target as vbase
    set Source = getvbase ("Bird-1")
    set Target = getvbase ("Dummy1")
    set M1.source = Source
    set M1.target = Target
    M1.applicationactive = true
    M1.developmentactive = true

    success = M1.construct("Motionlink-2")    'create Motionlink-2

        if Retrieve("NumberofBirds") = "2" then
     dim B2 as new Bird
     B2.Sensitivity = 95
     B2.serialbaudrate = 115200
     B2.unit = 2
     success = B2.Construct ("Bird-2")                  'create bird-2

     dim M2 as new MotionLink
     set Source = getvbase ("Bird-2")
     set Target = getvbase ("Dummy2")
     set M2.source = Source
     set M2.target = Target
     M2.applicationactive = true
     M2.developmentactive = true

     success = M2.construct("Motionlink-3")  'create Motionlink-3
    end if

Case "Console"

   InitServer(27)  ' Start LastPhobiaServer2.dll
    set human = getMovable ("humanclient")
        human.enabled = false                                'disable client scripts
    set human = getMovable ("humanserver")
        human.enabled = true                                 'enable server scripts
    set human = getMovable ("head")
        human.enabled = true                                 'enable head

        set scr = getWindow ("Fullscreen-LeftEye")
    set vp = getViewpoint ("Eye")
        set scr.Viewpoint = vp
        scr.LeftEdge = 511
        scr.Width = 350
        scr.Height = 225
        scr.TopEdge = 116
        scr.YonClipping = 5e+025

        set scr = getWindow ("Fullscreen-RightEye")
   set vp = getViewpoint ("FreeVP")
        vp .translate 0,-50,-100
        set scr.Viewpoint = vp
    scr.LeftEdge = 511
        scr.Width = 350
        scr.Height = 225
        scr.TopEdge = 460
```

```
            scr.YonClipping = 5e+025

    end select

'*** Avatar-image loading ***
  dim Avatar as Avatar
  dim iter as iterator
  dim poly as long
  dim PicNoStr as String
  dim i as integer
  dim poster as imported
  dim node as node
  dim result as boolean
  set Avatar = getfirstAvatar(iter)
  while (Avatar is not nothing)
    for i = 1 to Avatar.NumChildren
      set Node = Avatar.GetChild(i-1)
            set Poster = CastToImported(Node)
            result = ForkImported (Poster)
      if i < 10 then
        PicNoStr = "0" + CSTR(i)
      else
        PicNoStr = CSTR(i)
      end if
      PicNoStr = Avatar.ImageName + PicNoStr

      if ThisCompu$ = "Console" then PicNoStr = "l" + Right$(PicNoStr,len(PicNoStr)-1)

      poly = Poster.GetFirstPoly()
      Poster.SetPolyTexture poly, PicNoStr, FALSE, TRUE
    next i
    set Avatar = getnextAvatar(iter)
  wend
  Message "Avatar Imagefiles loaded"
end sub
```

Mshutdown

```
declare sub KillClient stdcall lib "c:\DLLs\PhobiaClient.dll"
declare sub KillServer stdcall lib "c:\DLLs\SimpleServer.dll"

global ThisCompu$

sub main( )
  Select Case ThisCompu$
    Case "VRstation"
      KillClient
    Case "Console"
      KillServer
    End Select
end sub
```

MMetroControl

```
'*** MMetroControl ***

global StartTime!

global OldMetroStatus&
global OldMetroMoves&

sub task( obj as Humans )
     dim Metro as Metrotype

     dim Path as Path
            dim Path2 as Path
            dim Path3 as Path
            dim Path4 as Path
            dim Path5 as Path
```

```
        dim Door1 as Path
        dim Door2 as Path
        dim Door3 as Path
        dim Door4 as Path

        dim DoorO1 as Path
        dim DoorO2 as Path
        dim DoorO3 as Path
        dim DoorO4 as Path

        dim Blocks as Path

        dim Sound1 as Sound

    set Metro = getMetrotype("Metro")

        if  not Metro.MetroStatus = OldMetroStatus then

                set Path = getPath("Move-Station1")
                Path.Rewind
                Path.Stop
                set Path = getPath("Move-Fast")
                Path.Rewind
                Path.Stop
                set Path = getPath("Move-Fast3")
                Path.Rewind
                Path.Stop
                set Path = getPath("Move-Fast4")
                Path.Rewind
                Path.Stop
                set Path = getPath("Stop-Station1")
                Path.Rewind
                Path.Stop

                set DoorO1 = getPath("Door1-Open")
                DoorO1.Rewind
                DoorO1.Stop
                set Door1 = getPath("Door1-Close")
                Door1.Rewind
                Door1.Stop

                set DoorO2 = getPath("Door2-Open")
                DoorO2.Rewind
                DoorO2.Stop
                set Door2 = getPath("Door2-Close")
                Door2.Rewind
                Door2.Stop

                set DoorO3 = getPath("Door3-Open")
                DoorO3.Rewind
                DoorO3.Stop
                set Door3 = getPath("Door3-Close")
                Door3.Rewind
                Door3.Stop

                set DoorO4 = getPath("Door4-Open")
                DoorO4.Rewind
                DoorO4.Stop
                set Door4 = getPath("Door4-Close")
                Door4.Rewind
                Door4.Stop

                set Blocks = getPath("BlockS")
                Blocks.Rewind
                Blocks.Stop
```

```
                set Sound1 = getSound("Engine")
                Sound1.Volume = 0
                Sound1.Stop
        end if

'*** Metro Moves ***

        if Metro.MetroStatus = 1 and Metro.MetroMoves = True then
if not Metro.MetroStatus = OldMetroStatus or not Metro.MetroMoves = OldMetroMoves then
                set Sound1 = getSound("Engine")
                Sound1.Play
                Sound1.Volume = 1
                end if

                set Path = getPath("Move-Station1")
                Path.Play1

                if Path.CurrentElement = Path.Elements then
                        Path.Stop
                        set Path2 = getPath("Move-Fast")
                        Path2.Play1

                        if Path2.CurrentElement = Path2.Elements then

                        Path2.Stop
                        set Path3 = getPath("Move-Fast3")
                        Path3.Play1

                        if Path3.CurrentElement = Path3.Elements then
                Path3.Stop
                set Path4 = getPath("Move-Fast4")
                Path4.Play1

                if Path4.CurrentElement = Path4.Elements then

                Path4.Stop
                set Path5 = getPath("Stop-Station1")
                Path5.Play1

                if Path5.CurrentElement = Path5.Elements then
                'set Sound1 = getSound("Engine")
                'Sound1.Volume = 0.25

                Path5.Stop
                'Open the Doors
                set DoorO1 = getPath("Door1-Open")
                set DoorO2 = getPath("Door2-Open")
                set DoorO3 = getPath("Door3-Open")
                set DoorO4 = getPath("Door4-Open")

                DoorO1.Play1
                DoorO2.Play1
                DoorO3.Play1
                DoorO4.Play1

if DoorO1.CurrentElement = DoorO1.Elements and DoorO2.CurrentElement = DoorO2.Elements and
DoorO3.CurrentElement=DoorO3.Elements and DoorO4.CurrentElement=DoorO4.Elements then
                        DoorO1.Stop
                        DoorO2.Stop
                        DoorO3.Stop
                        DoorO4.Stop
                        set Blocks = getPath("BlockS")
                        Blocks.Play
                        if Blocks.CurrentElement = Blocks.Elements then

                        Blocks.Stop
```

```
                'Closing the Doors
                set Door1 = getPath("Door1-Close")
                Door1.Play
                set Door4 = getPath("Door4-Close")
                Door4.Play
                set Door2 = getPath("Door2-Close")
                set Door3 = getPath("Door3-Close")
                Door2.Play
                Door3.Play



if Door1.CurrentElement = Door1.Elements and Door2.CurrentElement = Door2.Elements and
Door3.CurrentElement=Door3.Elements and Door4.CurrentElement=Door4.Elements then
                Door1.Stop
                Door2.Stop
                Door3.Stop
                Door4.Stop
                Metro.MetroStatus = 0
                        end if
                        end if
                        end if
                        end if
                        end if
                        end if
                end if
                end if

        end if

'****Metro Stands Still
        if Metro.MetroMoves = False then
        set Sound1 = getSound("Engine")
        Sound1.Volume = 0

 end if

'****Metro Must Stop in the Stasion 1
        If Metro.MetroStatus = 2 and Metro.MetroMoves = True then

        if not Metro.MetroStatus = OldMetroStatus then
                set Sound1 = getSound("Engine")
                Sound1.Play
                Sound1.Volume = 1
        end if

    set Path = getPath("Stop-Station1")
         Path.Play1

         if Path.CurrentElement = Path.Elements then
                set Sound1 = getSound("Engine")
                Sound1.Volume = 0

                Path.Stop

                'Open the Doors
                set DoorO1 = getPath("Door1-Open")
                set DoorO2 = getPath("Door2-Open")
                set DoorO3 = getPath("Door3-Open")
                set DoorO4 = getPath("Door4-Open")

                DoorO1.Play1
                DoorO2.Play1
                DoorO3.Play1
                DoorO4.Play1
```

```
if DoorO1.CurrentElement = DoorO1.Elements and DoorO2.CurrentElement = DoorO2.Elements and
DoorO3.CurrentElement=DoorO3.Elements and DoorO4.CurrentElement=DoorO4.Elements then
                        DoorO1.Stop
                        DoorO2.Stop
                        DoorO3.Stop
                        DoorO4.Stop
                        set Blocks = getPath("BlockS")
                        Blocks.Play1

                        if Blocks.CurrentElement = Blocks.Elements then
                                Blocks.Stop

                                'Closing the Doors
                                set Door1 = getPath("Door1-Close")
                                Door1.Play
                                set Door4 = getPath("Door4-Close")
                                Door4.Play

                                set Door2 = getPath("Door2-Close")
                                set Door3 = getPath("Door3-Close")
                                Door2.Play
                                Door3.Play



if Door1.CurrentElement = Door1.Elements and Door2.CurrentElement = Door2.Elements and
Door3.CurrentElement=Door3.Elements and Door4.CurrentElement=Door4.Elements then
                                        Door1.Stop
                                        Door2.Stop
                                        Door3.Stop
                                        Door4.Stop
                                        Metro.MetroStatus = 2
                                end if
                                end if
                                end if

                                end if
                                end if
        OldMetroStatus = Metro.MetroStatus
        OldMetroMoves = Metro.MetroMoves

end sub
```

Menvironment Control

```
public E1!, E2!, E3!, E4!, E5!, E6!, E7!, E8!, E9!, E10!
public OldE5!, OldE1!, OldE2!, OldE6!


sub task( obj as Imported )

  dim Metro as MetroType

  set Metro = getMetroType("Metro")
  Metro.MetroStatus = E3!
  Metro.MetroMoves = E7!

  dim Avatar1 as Avatar
  dim Avatar2 as Avatar
  dim Avatar4 as Avatar
  dim Avatar5 as Avatar
  dim Avatar6 as Avatar
  dim Avatar7 as Avatar
  dim Avatar8 as Avatar
  dim Avatar9 as Avatar
  dim Avatar11 as Avatar

  dim Avatar12 as Avatar2
```

```
dim Avatar14 as Avatar2
dim Avatar15 as Avatar2
dim Avatar17 as Avatar2
dim Avatar20 as Avatar2
dim Avatar21 as Avatar2

dim AvaTrans as Vect3D
dim AvaRot as Orientation

if not OldE1! = E1! then
        set Avatar5 = getAvatar("Avatar-5")
        set Avatar6 = getAvatar("Avatar-6")
        set Avatar8 = getAvatar("Avatar-8")
        set Avatar9 = getAvatar("Avatar-9")

        set Avatar1 = getAvatar("Avatar-1")
        set Avatar2 = getAvatar("Avatar-2")

        set Avatar4 = getAvatar("Avatar-4")

        set Avatar7 = getAvatar("Avatar-7")
        set Avatar10 = getAvatar("Avatar-10")
        set Avatar11= getAvatar("Avatar-11")

        set Avatar12 = getAvatar2("MAvatar1")

        set Avatar14 = getAvatar2("MAvatar3")
        set Avatar15 = getAvatar2("MAvatar4")

        set Avatar17 = getAvatar2("MAvatar6")


        set Avatar20 = getAvatar2("MAvatar9")
        set Avatar21 = getAvatar2("MAvatar10")



        select case E1!
                case 1

                        AvaTrans.x = -195.826
                        AvaTrans.y = -62.0457
                        AvaTrans.z = -373.006
                        Avatar1.SetTranslation AvaTrans
                        AvaTrans.x = -185.463
                        AvaTrans.y = -63.5681
                        AvaTrans.z = -268.386
                        Avatar2.SetTranslation AvaTrans

                        AvaTrans.x = -2.02959
                        AvaTrans.y = -62
                        AvaTrans.z = -268.587
                        Avatar4.SetTranslation AvaTrans


                        AvaTrans.x = -82.4024
                        AvaTrans.y = -81.8007
                        AvaTrans.z = -99.8456
                        Avatar5.SetTranslation AvaTrans
                        AvaTrans.x = -205.745
                        AvaTrans.y = -91.5
                        AvaTrans.z = -54.002
                        Avatar6.SetTranslation AvaTrans
                        AvaTrans.x = -208.135
                        AvaTrans.y = -84.2165
                        AvaTrans.z = -182.87
                        Avatar8.SetTranslation AvaTrans
```

```
        AvaTrans.x = -15.6402
        AvaTrans.y = -78.201
        AvaTrans.z = -28.8742
        Avatar9.SetTranslation AvaTrans

        AvaTrans.x = -237.61
        AvaTrans.y = -52.2969
        AvaTrans.z = -261.07
        Avatar7.SetTranslation AvaTrans

        AvaTrans.x = -45.1154
        AvaTrans.y = -67
        AvaTrans.z = -261.07
        Avatar11.SetTranslation AvaTrans

        AvaRot.x = 0
        AvaRot.y = -1
        AvaRot.z = 0
        AvaRot.w = -8e-006

        AvaTrans.x = -42.6093
        AvaTrans.y = -62
        AvaTrans.z = -520.4
        Avatar12.SetTranslation AvaTrans
        Avatar12.SetRotation AvaRot

        AvaTrans.x = -5.11
        AvaTrans.y = -81.81
        AvaTrans.z = -933.425
        Avatar14.SetTranslation AvaTrans
        Avatar14.SetRotation AvaRot
        AvaTrans.x = -43.75
        AvaTrans.y = -72.16
        AvaTrans.z = -936.83
        Avatar15.SetTranslation AvaTrans
        Avatar15.SetRotation AvaRot

        AvaTrans.x = -217.023
        AvaTrans.y = -47.7223
        AvaTrans.z = -877.75
        Avatar17.SetTranslation AvaTrans
        Avatar17.SetRotation AvaRot


        AvaTrans.x = -201.116
        AvaTrans.y = -74.9923
        AvaTrans.z = -1056.71
        Avatar20.SetTranslation AvaTrans
        Avatar20.SetRotation AvaRot
        AvaTrans.x = -271.563
        AvaTrans.y = -85.7866
        AvaTrans.z = -864.115
        Avatar21.SetTranslation AvaTrans
        Avatar21.SetRotation AvaRot

case 2
        AvaTrans.x = -195.826
        AvaTrans.y = -62.0457
        AvaTrans.z = -373.006
        Avatar1.SetTranslation AvaTrans
        AvaTrans.x = -185.463
        AvaTrans.y = -63
        AvaTrans.z = -277.476
        Avatar2.SetTranslation AvaTrans

        AvaTrans.x = -2.02959
        AvaTrans.y = -62
```

```
AvaTrans.z = -268.587
Avatar4.SetTranslation AvaTrans


AvaTrans.x = -82.4024
AvaTrans.y = -81.8007
AvaTrans.z = -99.8456
Avatar5.SetTranslation AvaTrans
AvaTrans.x = -205.745
AvaTrans.y = -91.5
AvaTrans.z = -31.2775
Avatar6.SetTranslation AvaTrans
AvaTrans.x = -208.135
AvaTrans.y = -84.2165
AvaTrans.z = -182.87
Avatar8.SetTranslation AvaTrans
AvaTrans.x = -25.2983
AvaTrans.y = -78.201
AvaTrans.z = -28.8742
Avatar9.SetTranslation AvaTrans

AvaTrans.x = -237.61
AvaTrans.y = -52.2969
AvaTrans.z = -261.07
Avatar7.SetTranslation AvaTrans

AvaTrans.x = -45.1154
AvaTrans.y = -67
AvaTrans.z = -261.07
Avatar11.SetTranslation AvaTrans

AvaRot.x = 0
AvaRot.y = -1
AvaRot.z = 0
AvaRot.w = -8e-006

AvaTrans.x = -42.6093
AvaTrans.y = -62
AvaTrans.z = -520.4
Avatar12.SetTranslation AvaTrans
Avatar12.SetRotation AvaRot

AvaTrans.x = -5.11
AvaTrans.y = -81.81
AvaTrans.z = -933.425
Avatar14.SetTranslation AvaTrans
Avatar14.SetRotation AvaRot
AvaTrans.x = -43.75
AvaTrans.y = -72.16
AvaTrans.z = -936.83
Avatar15.SetTranslation AvaTrans
Avatar15.SetRotation AvaRot

AvaTrans.x = -217.023
AvaTrans.y = -47.7223
AvaTrans.z = -877.75
Avatar17.SetTranslation AvaTrans
Avatar17.SetRotation AvaRot


AvaTrans.x = -201.116
AvaTrans.y = -74.9923
AvaTrans.z = -1056.71
Avatar20.SetTranslation AvaTrans
Avatar20.SetRotation AvaRot
AvaTrans.x = -271.563
AvaTrans.y = -85.7866
```

```
        AvaTrans.z = -864.115
        Avatar21.SetTranslation AvaTrans
        Avatar21.SetRotation AvaRot

case 3

        AvaTrans.x = -195.826
        AvaTrans.y = -62.0457
        AvaTrans.z = -876.365
        Avatar1.SetTranslation AvaTrans
        AvaTrans.x = -185.463
        AvaTrans.y = -63
        AvaTrans.z = -958.656
        Avatar2.SetTranslation AvaTrans

        AvaTrans.x = 21.2635
        AvaTrans.y = -72.7944
        AvaTrans.z = -1016.24
        Avatar4.SetTranslation AvaTrans


        AvaTrans.x = -82.4024
        AvaTrans.y = -81.8007
        AvaTrans.z = -710.578
        Avatar5.SetTranslation AvaTrans
        AvaTrans.x = -226.766
        AvaTrans.y = -91.5
        AvaTrans.z = -652.805
        Avatar6.SetTranslation AvaTrans
        AvaTrans.x = -208.135
        AvaTrans.y = -84.2165
        AvaTrans.z = -768.036
        Avatar8.SetTranslation AvaTrans
        AvaTrans.x = -15.6402
        AvaTrans.y = -78.201
        AvaTrans.z = -648.695
        Avatar9.SetTranslation AvaTrans

        AvaTrans.x = -237.61
        AvaTrans.y = -66.5
        AvaTrans.z = -866.689
        Avatar7.SetTranslation AvaTrans

        AvaTrans.x = -45.1154
        AvaTrans.y = -39.7299
        AvaTrans.z = -1019.52
        Avatar11.SetTranslation AvaTrans

        AvaRot.x = 0
        AvaRot.y = 0
        AvaRot.z = 0
        AvaRot.w = 1

        AvaTrans.x = -247.134
        AvaTrans.y = -71.3836
        AvaTrans.z = -252.247
        Avatar12.SetTranslation AvaTrans
        Avatar12.SetRotation AvaRot

        AvaTrans.x = -226.113
        AvaTrans.y = -82.9461
        AvaTrans.z = -474.951
        Avatar14.SetTranslation AvaTrans
        Avatar14.SetRotation AvaRot
        AvaTrans.x = -178.959
        AvaTrans.y = -72.1517
        AvaTrans.z = -572.668
```

```
        Avatar15.SetTranslation AvaTrans
        Avatar15.SetRotation AvaRot

        AvaTrans.x = -42.0411
        AvaTrans.y = -47.7223
        AvaTrans.z = -570.395
        Avatar17.SetTranslation AvaTrans
        Avatar17.SetRotation AvaRot

        AvaTrans.x = 6.24935
        AvaTrans.y = -77.8329
        AvaTrans.z = -553.352
        Avatar20.SetTranslation AvaTrans
        Avatar20.SetRotation AvaRot
        AvaTrans.x = -42.6092
        AvaTrans.y = -85.7866
        AvaTrans.z = -249.406
        Avatar21.SetTranslation AvaTrans
        Avatar21.SetRotation AvaRot


case 4
        AvaTrans.x = -195.826
        AvaTrans.y = -62.0457
        AvaTrans.z = -876.364
        Avatar1.SetTranslation AvaTrans
        AvaTrans.x = -185.463
        AvaTrans.y = -64.1362
        AvaTrans.z = -965.473
        Avatar2.SetTranslation AvaTrans

        AvaTrans.x = -2.02959
        AvaTrans.y = -62
        AvaTrans.z = -945.221
        Avatar4.SetTranslation AvaTrans


        AvaTrans.x = -82.4024
        AvaTrans.y = -81.8007
        AvaTrans.z = -710.578
        Avatar5.SetTranslation AvaTrans
        AvaTrans.x = -226.766
        AvaTrans.y = -91.5
        AvaTrans.z = -652.805
        Avatar6.SetTranslation AvaTrans
        AvaTrans.x = -208.135
        AvaTrans.y = -84.2165
        AvaTrans.z = -768.036
        Avatar8.SetTranslation AvaTrans
        AvaTrans.x = -15.6402
        AvaTrans.y = -78.201
        AvaTrans.z = -648.695
        Avatar9.SetTranslation AvaTrans

        AvaTrans.x = -237.61
        AvaTrans.y = -66.5
        AvaTrans.z = -866.689
        Avatar7.SetTranslation AvaTrans

        AvaTrans.x = -45.1154
        AvaTrans.y = -67
        AvaTrans.z = -948.5
        Avatar11.SetTranslation AvaTrans

        AvaRot.x = 0
        AvaRot.y = 0
        AvaRot.z = 0
```

```
                        AvaRot.w = 1

                        AvaTrans.x = -247.134
                        AvaTrans.y = -71.3836
                        AvaTrans.z = -252.247
                        Avatar12.SetTranslation AvaTrans
                        Avatar12.SetRotation AvaRot

                        AvaTrans.x = -226.113
                        AvaTrans.y = -82.9461
                        AvaTrans.z = -474.951
                        Avatar14.SetTranslation AvaTrans
                        Avatar14.SetRotation AvaRot
                        AvaTrans.x = -178.959
                        AvaTrans.y = -72.1517
                        AvaTrans.z = -572.668
                        Avatar15.SetTranslation AvaTrans
                        Avatar15.SetRotation AvaRot

                        AvaTrans.x = -42.0411
                        AvaTrans.y = -47.7223
                        AvaTrans.z = -570.395
                        Avatar17.SetTranslation AvaTrans
                        Avatar17.SetRotation AvaRot


                        AvaTrans.x = 6.24935
                        AvaTrans.y = -77.8329
                        AvaTrans.z = -553.352
                        Avatar20.SetTranslation AvaTrans
                        Avatar20.SetRotation AvaRot
                        AvaTrans.x = -42.6092
                        AvaTrans.y = -85.7866
                        AvaTrans.z = -249.406
                        Avatar21.SetTranslation AvaTrans
                        Avatar21.SetRotation AvaRot
        end select

end if

if not OldE2! = E2! then
        set Avatar1 = getAvatar("Avatar-1")
        set Avatar2 = getAvatar("Avatar-2")

        set Avatar4 = getAvatar("Avatar-4")
        set Avatar5 = getAvatar("Avatar-5")
        set Avatar6 = getAvatar("Avatar-6")
        set Avatar7 = getAvatar("Avatar-7")
        set Avatar8 = getAvatar("Avatar-8")
        set Avatar9 = getAvatar("Avatar-9")

        set Avatar11 = getAvatar("Avatar-11")

        set Avatar12 = getAvatar2("MAvatar1")

        set Avatar14 = getAvatar2("MAvatar3")
        set Avatar15 = getAvatar2("MAvatar4")
        set Avatar17 = getAvatar2("MAvatar6")


        set Avatar20 = getAvatar2("MAvatar9")
        set Avatar21 = getAvatar2("MAvatar10")


        select case E2!
                case 0
                        Avatar1.Enabled = false
```

```
                    Avatar2.Enabled = false

                    Avatar4.Enabled = false
                    Avatar5.Enabled = false
                    Avatar6.Enabled = false
                    Avatar7.Enabled = false
                    Avatar8.Enabled = false
                    Avatar9.Enabled = false

                    Avatar11.Enabled = false
                    Avatar12.Enabled = false

                    Avatar14.Enabled = false
                    Avatar15.Enabled = false

                    Avatar17.Enabled = false


                    Avatar20.Enabled = false
                    Avatar21.Enabled = false

                    case 1
                    Avatar1.Enabled = true
                    Avatar2.Enabled = true

                    Avatar4.Enabled = false
                    Avatar5.Enabled = true
                    Avatar6.Enabled = false
                    Avatar7.Enabled = false
                    Avatar8.Enabled = true
                    Avatar9.Enabled = false
                    Avatar12.Enabled = false

                    Avatar14.Enabled = false
                    Avatar15.Enabled = false

                    Avatar17.Enabled = false


                    Avatar20.Enabled = false
                    Avatar21.Enabled = false


          case 2
                    Avatar1.Enabled = true
                    Avatar2.Enabled = true

                    Avatar4.Enabled = true
                    Avatar5.Enabled = true
                    Avatar6.Enabled = true
                    Avatar7.Enabled = true
                    Avatar8.Enabled = true
                    Avatar9.Enabled = true

                    Avatar11.Enabled = true
                    Avatar12.Enabled = true

                    Avatar14.Enabled = true
                    Avatar15.Enabled = true

                    Avatar17.Enabled = true

                    Avatar20.Enabled = true
                    Avatar21.Enabled = true


end select
```

```
  end if


  dim Light as Light
  set Light = getLight("Light-1")

  dim Light2 as Light
  set Light2 = getLight("PointLight-1")


  if not OldE5! = E5! then

        dim Lamps1 as Switcher
        dim Lamps2 as Switcher
        set Lamps1 = getSwitcher("Lamps-1")
        set Lamps2 = getSwitcher("Lamps-2")

        Lamps1.activechild = E5!
        Lamps2.activechild = E5!

        select case E5!
         case 0
              Light.Enabled = True
       Light2.Enabled = True

         case 1
              Light.Enabled = False
              Light2.Enabled = False

        end select
  end if

  if not OldE6! = E6! then
        dim Sound2 as Sound
        set Sound2 = getSound("People")

        select case E6!
              case 0
                    Sound2.Stop
                    Sound2.Volume = 0
              case 1
                    Sound2.Play
                    Sound2.Volume = 0.65
        end select

  end if

  OldE1! = E1!
  OldE2! = E2!
  OldE5! = E5!
  OldE6! = E6!
end sub
```

Appendix D: User Interface Program

```
unit SimpleServerForm;

interface

uses
  Windows, Messages, SysUtils, Classes, Graphics, Controls, Forms, Dialogs,
  ScktComp, StdCtrls, ExtCtrls, ComCtrls, Buttons,
  DBCtrls, Spin, Gauges, Grids, DBGrids, TeEngine, Series,
  TeeProcs, Chart, DBChart, Db, DBTables, Mask, ImgList, CoolForm;

type

  TSendThread = class(TThread)
  protected
    procedure Execute; override;
    constructor Create(CreateSuspended: Boolean);
  end;

  TCoordinates = record
    x,y,z,p,q,r,w : single;     {28 bytes}
  end;

  TJoystick = record
    x,y : single;              {8}
    b1,b2 : integer;            {8}
  end;                         {16 bytes total}

  TOutputData = record
    Joystick : TJoystick;       {16}
    AutoPilot : TCoordinates;   {28 nav point coords for autopilot}
    APStatus : single;          {4  autopilot status}
    Environment : array[1..10] of single; {40}
    CommStat : integer;         {4}
  end;                         {92 bytes total}

  TInputData = record
    human : TCoordinates;       {28}
    viewpoint : TCoordinates;   {28}
    ExtraCoords: TCoordinates;  {28 Extra coords, for airplane in world 10}
    Commstat: integer;          {4}
  end;                         {88 bytes total}

  TInternalData = record
    CtrlX, CtrlY, CtrlLeftRight, CtrlUpDown, CtrlReset,
    CtrlSpeed, CtrlPatient, CtrlPoint : single;
    FreeViewpoint : TCoordinates;
  end;

  TSimpleServerForm = class(TForm)
    PatientViewGroup: TGroupBox;
    FreeViewpointGroup: TGroupBox;
    Image1: TImage;
    Image2: TImage;

    CloseButton: TBitBtn;

    Statusgroup: TGroupBox;
    Label100: TLabel;
    LocationLabel: TLabel;
    Label101: TLabel;
    Label102: TLabel;
    NWrec: TLabel;
    NWsnd: TLabel;
    NetworkTimer: TTimer;
    Timer1: TTimer;
```

```
  ServerSocket1: TServerSocket;
  ClientSocket1: TClientSocket;
  CoolForm1: TCoolForm;
  MapGroup: TGroupBox;
  MapBackground: TImage;
  MapYouAreHere: TImage;
  NP1: TImage;
  NP2: TImage;
  NP3: TImage;
  NP4: TImage;
  Image3: TImage;
  PatientLocation: TLabel;
  Control1: TGroupBox;
  PeopleControl: TGroupBox;
  RadioButton1: TRadioButton;
  RadioButton2: TRadioButton;
  RadioButton3: TRadioButton;
  SeatControl: TGroupBox;
  LightControl: TGroupBox;
  LightOn: TRadioButton;
  RadioButton5: TRadioButton;
  Label1: TLabel;
  Image4: TImage;
  Label2: TLabel;
  Control2: TGroupBox;
  MetroControl: TGroupBox;
  RadioButton6: TRadioButton;
  RadioButton7: TRadioButton;
  StandingStillCheck: TCheckBox;

  procedure ServerSocket1ClientRead(Sender: TObject;
    Socket: TCustomWinSocket);
  procedure SendData;
  procedure FormCreate(Sender: TObject);
  procedure ServerSocket1Accept(Sender: TObject;
    Socket: TCustomWinSocket);
  procedure ServerSocket1ClientDisconnect(Sender: TObject;
    Socket: TCustomWinSocket);
  procedure CloseButtonClick(Sender: TObject);
  procedure FormShow(Sender: TObject);

  procedure NetworkTimerTimer(Sender: TObject);
  procedure ClientSocket1Connect(Sender: TObject;
    Socket: TCustomWinSocket);
  procedure ClientSocket1Error(Sender: TObject; Socket: TCustomWinSocket;
    ErrorEvent: TErrorEvent; var ErrorCode: Integer);
  procedure Timer1Timer(Sender: TObject);
  procedure NP1Click(Sender: TObject);
  procedure NP2Click(Sender: TObject);
  procedure NP3Click(Sender: TObject);
  procedure NP4Click(Sender: TObject);
  procedure LightOnClick(Sender: TObject);
  procedure LightOffClick(Sender: TObject);
  procedure MovingClick(Sender: TObject);
  procedure StoppingClick(Sender: TObject);
  procedure StandingStillClick(Sender: TObject);
  procedure PeopleNoneClick(Sender: TObject);
  procedure PeopleFewClick(Sender: TObject);
  procedure PeopleManyClick(Sender: TObject);




private
  SendThread          : TSendThread;
  SendThreadAvailable : Boolean;
```

```
    NWrecCount,NWsndCount : integer;
    AutopilotRun          : integer;
    procedure UpdateValues;
    function Retrieve (param : string) : string;
    procedure StartClientApp;
    procedure StartServerSocket;
  public
    LocationID   : Integer;
    CommState    : integer;           //State of the connection
    InputData    : TInputData;        //Data received from the client
    OutputData   : TOutputData;       //Data to be send to the client
    InternalData : TInternalData;     //Data that is shared with the WUP player on the server
    procedure ReloadCtrl;
  end;

var
  CSForm: TSimpleServerForm;

Const
  CSNotConnected = 0;
  CSConnected = 1;
  CSExchanging = 2;
  CSShuttingDown = 99;

implementation

{$R *.DFM}



//Creates the form and initializes some variables
procedure TSimpleServerForm.FormCreate(Sender: TObject);
begin
  SendThreadAvailable := true;
  CommState := CSNotConnected;            {Communications are down}
  OutputData.CommStat := CSNotConnected;
  label100.caption := 'Wait for the connection';
  ReloadCtrl;
  AutopilotRun :=0; //not running
  StartServerSocket;
  StartClientApp;
end;

Procedure TSimpleServerForm.StartServerSocket;
begin
  ServerSocket1.Port := StrtoInt(Retrieve('PortConsole'));
  ServerSocket1.Open;
end;

//Procedure to automatically start the client on the other computer
Procedure TSimpleServerForm.StartClientApp;
begin
  ClientSocket1.Address := Retrieve('IPVRstation');
  ClientSocket1.Port := StrtoInt(Retrieve('PortVRstation'));
  ClientSocket1.Open;
end;

//What to do when client makes connection
procedure TSimpleServerForm.ServerSocket1Accept(Sender: TObject;
  Socket: TCustomWinSocket);
begin
  CommState := CSConnected;            {Connected}
  label100.caption := 'Connected';
end;

//What to do when client sends data
procedure TSimpleServerForm.ServerSocket1ClientRead(Sender: TObject;
```

```
  Socket: TCustomWinSocket);
begin
  Socket.ReceiveBuf(InputData,88);
  NWrecCount := NWrecCount + 1;
  if CommState = CSConnected then {Received}
  begin
    CommState := CSExchanging;
    label100.caption := 'Connection active';
  end;
  if InputData.Commstat=CSShuttingdown then {Disconnect}
  begin
    label100.caption := 'Bezig verbinding te verbreken';
    repeat until SendThreadAvailable;
    Outputdata.CommStat := 99;
    SendData;
    CommState:=CSNotConnected;
    label100.caption := 'Disconnect';
  end;
  UpdateValues;
end;

//This procedure is called when data is received from client
procedure TSimpleServerForm.UpdateValues;

  begin

  AutopilotRun :=0;

  end;

//Create a thread for sending data
procedure TSimpleServerForm.SendData;
begin
  if ((SendThreadAvailable) and (Commstate = CSExchanging)) then
  begin
    SendThread := TSendThread.Create(False);
    SendThreadAvailable := false;
    NWsndCount := NWsndCount + 1;
  end;
end;

//Sendthread constructor
constructor TSendThread.Create(CreateSuspended: Boolean);
begin
  inherited Create(CreateSuspended);
  Priority := tpNormal;
  FreeOnTerminate := True;
end;

//Send the data to the client (in a seperate thread)
procedure TSendThread.Execute;
begin
  CSForm.serversocket1.Socket.Connections[0].SendBuf(CSForm.OutputData,92);
  CSForm.SendThreadAvailable := true;
end;

//What to do when the client disconnects
procedure TSimpleServerForm.ServerSocket1ClientDisconnect(Sender: TObject;
  Socket: TCustomWinSocket);
begin
  if CommState = CSShuttingDown then OutputData.Environment[1] := 999; //Close the form
  CommState := CSNotConnected;        {disconnected}
  label100.caption := 'Disconnected';
end;

//Afsluit knop. Afsluiten gebeurt vanuit WUP player
procedure TSimpleServerForm.CloseButtonClick(Sender: TObject);
```

```
begin
  if CommState = CSExchanging then
  begin
    OutputData.CommStat := CSShuttingDown;
    repeat until SendThreadAvailable;
    SendData;
    CommState := CSShuttingDown;
    Label100.caption := 'Terminating client application';
  end
  else
    OutputData.Environment[1] := 999;
end;

//Show forms
procedure TSimpleServerForm.FormShow(Sender: TObject);
begin

  //Set default values

  OutputData.Environment[1] :=0;  //avatars location
  OutputData.Environment[2] :=0;  //avatars quantity (none)
  OutputData.Environment[3] :=0;  //metro status
  OutputData.Environment[5] :=0;  //light (on)
  OutputData.Environment[6] :=0; //avatars sound  (off)
  OutputData.Environment[7] :=1; //metro move (true)

end;

procedure TSimpleServerForm.ReloadCtrl;
begin
  with InternalData do
  begin
    CtrlSpeed := 5;{11-CtrlSpeedTrackbar.Position;}

    CtrlX := 0;
    CtrlY := 0;
    CtrlLeftRight := 0;
    CtrlUpDown := 0;
    CtrlReset := 0;
    CtrlPoint := 0;
  end;
end;

procedure TSimpleServerForm.NetworkTimerTimer(Sender: TObject);
begin
  SendData; //Send data on regular interval
end;

{ *** Retrieve ***                                    }
{ This function retrieves a line from the file c:\phobia.ini    }
{ that specifies paths, ipnumbers etc                       }
function TSimpleServerForm.Retrieve (param : string) : string;
var
  F : textfile;
  s : string;
begin
  assignfile(F, 'c:\phobia.ini');
  reset(F);
  while not EOF(F) do
  begin
    ReadLN(F,s);
    if Copy(s, 1, length(param)) = param then
      Result := Copy(s, length(param)+4, length(s)-length(param)-3);
  end;
  CloseFile(F);
end;
```

```
procedure TSimpleServerForm.ClientSocket1Connect(Sender: TObject;
  Socket: TCustomWinSocket);
begin
  Socket.SendText(Retrieve('VEfilename'+inttostr(LocationID)));
end;

procedure TSimpleServerForm.ClientSocket1Error(Sender: TObject;
  Socket: TCustomWinSocket; ErrorEvent: TErrorEvent;
  var ErrorCode: Integer);
begin
  label100.caption := 'Auto opstarten client gefaald';
  ErrorCode := 0;
end;

procedure TSimpleServerForm.Timer1Timer(Sender: TObject);
begin
  NWrec.caption := inttostr(NWrecCount);
  NWsnd.caption := inttostr(NWsndCount);
  NWrecCount := 0;
  NWsndCount := 0;
end;


procedure TSimpleServerForm.NP1Click(Sender: TObject);
var x,y,z,p,q,r,w :single;

begin

AutopilotRun :=1;

x :=0;
y :=-115;
z :=-332;

p :=0;
q :=0;
r :=0;
w :=1;

  OutputData.Autopilot.x :=x;
  OutputData.Autopilot.y :=y;
  OutputData.Autopilot.z :=z;
  OutputData.Autopilot.p :=p;
  OutputData.Autopilot.q :=q;
  OutputData.Autopilot.r :=r;
  OutputData.Autopilot.w :=w;
  OutputData.APStatus := 5.5;
  NP1.Visible :=False;
  NP2.Visible :=True;
  NP3.Visible :=True;
  NP4.Visible :=True;
  MapYouAreHere.Top := NP1.top;
  MapYouAreHere.Left := NP1.left;

  OutputData.Environment[1] := 1;

end;

procedure TSimpleServerForm.NP2Click(Sender: TObject);
var x,y,z,p,q,r,w :single;

begin

AutopilotRun :=1;

x :=0;
y :=-115;
```

```
z :=-1034;

p :=0;
q :=0;
r :=0;
w :=1;

  OutputData.Autopilot.x :=x;
  OutputData.Autopilot.y :=y;
  OutputData.Autopilot.z :=z;
  OutputData.Autopilot.p :=p;
  OutputData.Autopilot.q :=q;
  OutputData.Autopilot.r :=r;
  OutputData.Autopilot.w :=w;
  OutputData.APStatus := 5.5;
  NP1.Visible :=True;
  NP2.Visible :=False;
  NP3.Visible :=True;
  NP4.Visible :=True;

  MapYouAreHere.Top := NP2.top;
  MapYouAreHere.Left := NP2.left;

  OutputData.Environment[1]:=4;

end;


procedure TSimpleServerForm.NP3Click(Sender: TObject);
var x,y,z,p,q,r,w :single;

begin

AutopilotRun :=1;

x :=-50;
y :=-115;
z :=-834;

p :=0;
q :=0;
r :=0;
w :=1;

  OutputData.Autopilot.x :=x;
  OutputData.Autopilot.y :=y;
  OutputData.Autopilot.z :=z;
  OutputData.Autopilot.p :=p;
  OutputData.Autopilot.q :=q;
  OutputData.Autopilot.r :=r;
  OutputData.Autopilot.w :=w;
  OutputData.APStatus := 5.5;
  NP1.Visible :=True;
  NP2.Visible :=True;
  NP3.Visible :=False;
  NP4.Visible :=True;
  MapYouAreHere.Top := NP3.top;
  MapYouAreHere.Left := NP3.left;

  OutputData.Environment[1]:=3;

end;

procedure TSimpleServerForm.NP4Click(Sender: TObject);
var x,y,z,p,q,r,w :single;

begin
```

```
AutopilotRun :=1;

x :=-50;
y :=-115;
z :=-432;

p :=0;
q :=0;
r :=0;
w :=1;

  OutputData.Autopilot.x :=x;
  OutputData.Autopilot.y :=y;
  OutputData.Autopilot.z :=z;
  OutputData.Autopilot.p :=p;
  OutputData.Autopilot.q :=q;
  OutputData.Autopilot.r :=r;
  OutputData.Autopilot.w :=w;
  OutputData.APStatus := 5.5;
  NP1.Visible :=True;
  NP2.Visible :=True;
  NP3.Visible :=True;
  NP4.Visible :=False;

  MapYouAreHere.Top := NP4.top;
  MapYouAreHere.Left := NP4.left;

  OutputData.Environment[1]:=2;

end;

procedure TSimpleServerForm.LightOnClick(Sender: TObject);
begin
OutputData.Environment[5] :=0; //Light is on
end;

procedure TSimpleServerForm.LightOffClick(Sender: TObject);
begin
OutputData.Environment[5] := 1; //Light is off
end;

procedure TSimpleServerForm.MovingClick(Sender: TObject);
begin
OutputData.Environment[3] :=1;
end;

procedure TSimpleServerForm.StoppingClick(Sender: TObject);
begin
OutputData.Environment[3] :=2;
end;

procedure TSimpleServerForm.StandingStillClick(Sender: TObject);
begin
        if(sender as TCheckbox).Checked then
                OutputData.Environment[7] :=0
        else
                OutputData.Environment[7] :=1;
end;

procedure TSimpleServerForm.PeopleNoneClick(Sender: TObject);
begin
OutputData.Environment[2]:=0;
OutputData.Environment[6]:=0;
end;

procedure TSimpleServerForm.PeopleFewClick(Sender: TObject);
```

```
begin
OutputData.Environment[2] :=1;
OutputData.Environment[6] :=1;
end;

procedure TSimpleServerForm.PeopleManyClick(Sender: TObject);
begin
OutputData.Environment[2] :=2;
OutputData.Environment[6] :=1;
end;

end.
```

Abbreviations

DoF	Degree of Freedom
FOF	Fear of Flying
GUI	Graphical User Interface
HMD	Head-Mounted Display
PTSD	Post Traumatic Stress Disorder
SE	Standard Exposure
TA	Task Analysis
VE	Virtual Environment
VR	Virtual Reality
VRET	Virtual Reality Exposure Therapy
WTC	World Trade Center