Senseparation

March 13, 2014

Abstract

The interdisciplinary and experimental project focuses on the cross-border networking of people between virtual and real space. An encounter between two people takes place at different locations. Tactile, visual, and auditory perception are separated and therefore amplified in order to initiate an encounter. By means of an avatar, the user in virtual reality is able to interact with the person in the real space. Emotionless and distant encounters on a virtual level are experienced in a new way.

1 Introduction

Intense efforts in the field of Human Computer Interaction (HCI) are looking for possibilities to make the communication with the digital data more human and intuitive.
Based on this idea, we have developed a concept of a telehaptic encounter between two people in distant places. We decided to go beyond existing projects [11], mainly focusing on touch and added pictorial visualization and sound. This takes up the well-known habits of an encounter.
The sensory experience takes place in two different locations in order to better perceive the range of senses. We opted for the virtual space as the interface of the encounter to achieve a higher degree of immersion and presence and thus achieve an intensification of the encounter.
The goal was to stage a telehaptic performance with tactile feedback and to get information on triggered emotions. Therefore we selected three different touch patterns for the interaction with the avatar: hit, touch and bump.

Figure 1: VR user (left), dark room user with vest (center), spatial audio system of the dark room (right)

Figure 1 illustrates the virtual environment installation, the dark room user with the vest, and the a schematic sketch the spatial audio system.

2 Concept

In our experiment, one person is in a Virtual Reality (VR) installation, the other person is in a dark room equipped with a vest with vibration motors, compass and controller. The person in the dark room is represented as an avatar in the virtual world. The position and orientation of the avatar corresponds

to the position of the person in the dark room. The person in the VR installation is able to interact with the avatar and touch it by means of a sex degree of freedom input device. By touching the avatar, tactile feedback in the vibration vest is triggered at the contact points. In the virtual environments every single touch gives visual feedback on the avatar. Spatial audio in the dark room supports the representation of the proximity of the two people.
The following questions guided our experiment:

- Based on the dark room:
  - What emotions are triggered by the different haptic stimulations at the person in the darkroom? Are there triggered emotions?
  - Can specific touch patterns be associated with a particular person?
  - Is virtual proximity experienced as real human proximity?
  - What sensations are caused by the touch of the different body regions in the telehaptic communication?
  - What is perceived as pleasant or unpleasant?
  - How intense is the experience in different body regions?
- Based on the VR installation:
  - Does the design of the avatar fulfil the requirements of a human representation?
  - Does the user accept the avatar as a serious counterpart? Can we distinguish different people personalities projected through the avatar?
  - How do we visualize the approach to the second person?
  - Do we need a virtual design space in which the avatar is located or does it distract the encounter?
  - If so, how should the virtual space be designed to allow enough room for own imaginations?
  - What kind of visual feedback do we need after touching the avatar?
  - Do we need an acoustic presence of the avatar in the virtual world or is the visual presence sufficient?

3 Design

We designed the vest, the sound, the avatar and the VR environment in which the avatar shows up. The key design criterion was to adapt the four elements to the concept. We decided to give the design components a futuristic look.

3.1 Garment Design

Wearables show [11] or hide [8, 2] the used technology. We have combined both options to meet conceptional requirements. In our weareable design we played with the exciting contrast of cool, emotionless technology and warm, emotional materials like fabric. This idea represents our basic concept, where we combine human encounter, human proximity and thus warmness with functionality and cool technology. Some cables and the controller box are visible, the rest of the technical elements (vibration motors, controller and cables) are hidden.
First we thought of a long sleeve shirt. Finally made a decision for a vest, because it should fit everyone. We ultimately decided on a vest in triangular form and selected the attributes so that they were given a futuristic look. This strong design also supports the self-consciousness of the person in the dark room. We used rayon and gray felt (warm) as materials. We decorated these with red details (similar to a "network" pattern). We added a belt made of elastic band to ensure that the vest is tight enough. For extra stability we sewed in shoulder pads and a thick inlay on the top. Figure 2 shows the final Vest Design

Figure 2: Vibro-tactile vest from front (left) and side view (right).

3.2 Visual Design

The visual design concentrates on two aspects of the virtual world, the user representation as well as the representation of the actual environment.

3.2.1 Avatar

The degree of abstraction was a key element in the design of the avatar. First, the avatar should leave enough space to imagine the real person behind it. Second, it should be pleasant and not scary counterpart. Based on the research on the Uncanny Valley effects [7], we decided against a photo-realistic rendering of the avatar. Inspired by existing projects [1, 5, 9] we have chosen a visualization consisting of cubes. These cubes convert into a human silhouette when the two people come closer to each other as shown in Figure 3.

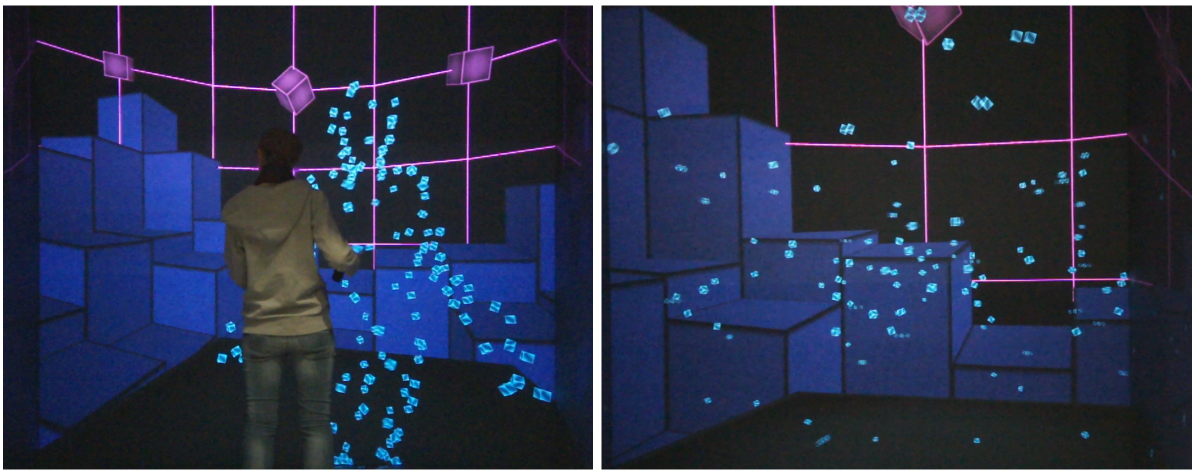

Figure 3: CAVE rendering with the avatar shape consisting of cubes (left) and a whirlwind-like distribution (right).

The color scheme is blue and thus quite neutral. The surface of the cubes show blue and white gradients. This gives the impression of light and lightness and makes the avatar appear friendly and carefree.

3.2.2 VR Environment

The VR environment for the avatar and the *real* person consists of two sections. The floor plate is the same size as the dark room. This is the area where the avatar and the real person can move, surrounded by a larger virtual globe. The sphere is open to the top and is only restricted by a wire frame combined with blocks. Looking up, you can see the universe. This design element reflects the networked encounter, the basic idea of the project. The lower part of the globe, in which the person is located, consists of a geometric architecture with blocks. This part of the virtual environment acts as a firm basis, balancing the weightlessness of the virtual world. Thus it gives safety for the participants. The colors are mostly in shades of blue with contrasting pink.

3.3 Sound Design

We use five separate sounds for the sonification of the VR user in the dark room: position and velocity, as well as the three touch patterns hit, touch, and bump.
Position and velocity sounds are constantly played back as is spatial sound in order to experience the exact location of the person in the VR installation and therefore the proximity of both participants. The position is represented by a harmonic and calm sound. The velocity is experienced by a heartbeat sample, repeated in the corresponding frequency, ranging from relaxed to nervous.
The sounds for hit, touch, and bump are played back once when the contact takes place. Hit and bump are represented by unpleasant sounds, while the touching sound is more neutral to leave the interpretation whether the touch is pleasant or unpleasant up to the person in the dark room.
The main concern of the sound design resides in not loosing these semiotic links: actions, like the hit or bump, need to be understandable acoustically without transporting the user to other mental places, suggesting other different actions out of context.

4 Technical Setup

Two locations interconnected by a network are required to experience the Senseparation installation, a dark room and a VR installation.
The dark room as well as the VR installation have each an alternative setup possibility, which is less demanding considering set-up constraints. The alternative setups are described in detail, including components and floorplans in the Appendix.

4.1 Dark Room

The dark room is equipped with position and orientation tracking for a single user and a spatial audio system. Additionally a vibro-tactile vest is provided for the user in the dark room. A communication server connects these components for exchanging data among them and the VR installation.

4.1.1 Communication Server

The communication server exchanges data between all components involved: VR installation, audio system, tracking, vibro-tactile vest. Figure 4 illustrates the data passed along by the server.

The VR installation's user position, velocity and action data is received, transformed and forwarded to the spatial audio system to move and play back the sound sources accordingly. The data, transformed for the audio system, is labelled as sound position, volume and id in the diagram. Additionally all action events are sent to the vest to trigger tactile output. The vest requires the id of the motor to activate, the strength of the motor vibration and a reset after the action is finished.
In return, the dark room user position data, received from the tracking system, and the orientation data, received from the vest, are forwarded to the VR installation for placing the avatar visualization.

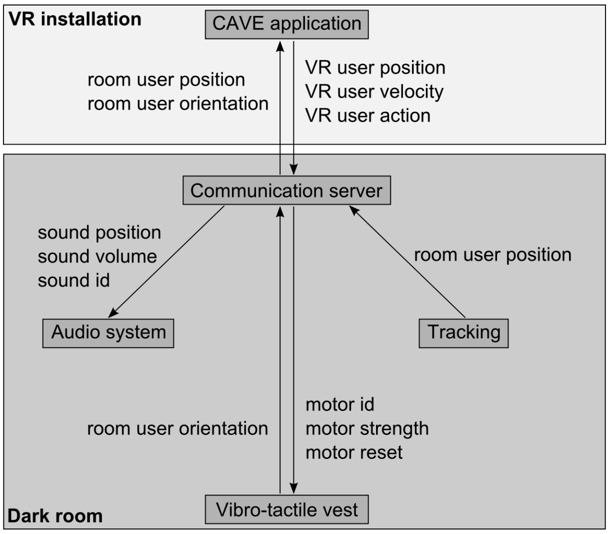

Figure 4: Data flow between all components

4.1.2 Audio System

The spatial audio system is realized in *Pure Data*[1], using the *Ambisonics* [6] technique. In our setup, the audio signal is sent to four individual speakers located in the corners of the dark room. Thus, if the VR installation's user is located in the upper right corner, the corresponding speaker will produce a continuous sound with a high intensity, the two adjacent speakers use less intensity and the opposite speaker is (almost) silent. If the user moves to another position, the intensity of the speaker will move consecutively.
The VR installation's user position is constantly played back as continuously moving sound in the spatial audio system, while the velocity of the user's movement re-triggers a heartbeat sound in corresponding beats per minute. The VR installation's user actions *hit*, *bump* and *touch* trigger separate sounds only during their occurrence.

4.1.3 Tracking

The tracking system consists of a single Kinect camera, used in depth mode, to capture the dark room user's position. The orientation of the user is sensed by a compass module integrated in the vibro-tactile vest.

4.1.4 Vibro-Tactile Vest

The garment consists of a vest, elbow cuffs and a belt, which are equipped with a total of 16 small vibration motors: 4 along the spine, 4 on each shoulder, as well as one on each elbow and hip. The motors are encased in 3D printed mounting plates and sewn onto the inside of the garment. The location of the motos is shown in Figure 5. An embedded micro controller (Arduino Pro Mini 3.3v) receives commands from the dark room computer via Bluetooth (HC05 Bluetooth module) and drives the motors accordingly.
To allow for a finer grain of detail, each motor can be driven using 64 steps of intensity using pulse width modulation. Due to the low frequency of the pulses, the motors can not only be actuated at different speeds, but can also generate a tingling sensation when using very short pulses that merely make the

[1]"Pure Data (aka Pd) is an open source visual programming language. Pd enables musicians, visual artists, performers, researchers, and developers to create software graphically, without writing lines of code. Pd is used to process and generate sound, video, 2D/3D graphics, and interface sensors, input devices, and MIDI. Pd can easily work over local and remote networks to integrate wearable technology, motor systems, lighting rigs, and other equipment. Pd is suitable for learning basic multimedia processing and visual programming methods as well as for realizing complex systems for large-scale projects."
Source: http://puredata.info/

motors jitter rather than rotate.
To allow for a more accurate orientation sensing than using only the Kinect, a compass module (Honeywell HMC6352) is connected to the Arduino's I2C bus and continuously sends its orientation to the dark room computer system at a resolution of 0.1 degrees. A lithium polymer battery provides the necessary power to drive the micro controller, Bluetooth module, compass and motors.

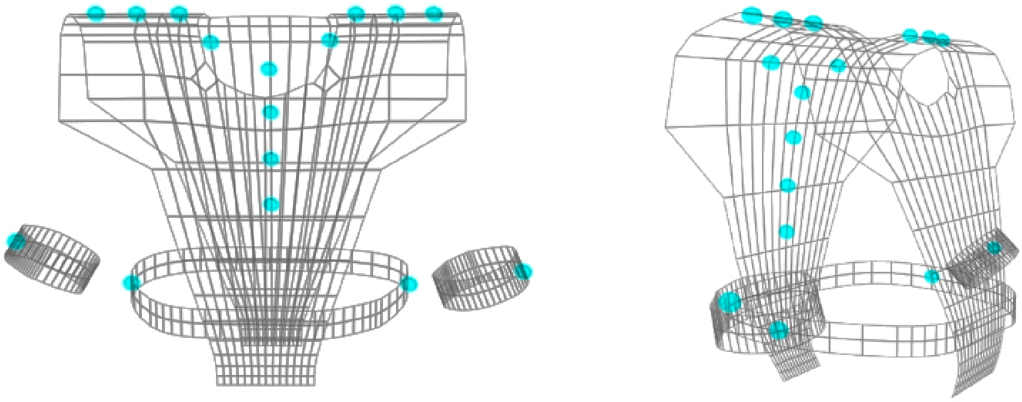

Figure 5: Location of the vest motors from front (left) and sideways (right).

4.2 Virtual World

The virtual world of Senseparation is the counterpart to the dark room. It is run on a VR installation and communicates via network with the communication server located at the dark room .

4.2.1 Hardware Components

The virtual world can be displayed with an arbitrary VR installation, that could for example be a stereoscopic multi-display installation or a Head Mounted Display (HMD).

CAVE Setup The tested set-up makes use of a 5-sided CAVE [4] installation incorporating a six degree of freedom (6DOF) optical tracking system. Multi-display installations are typically driven by cluster, which has significantly affected the application design from the software development point of view. This setup is hard to reproduce, since CAVEs are typically static installation at few locations.

HMD Setup An alternative, easily reproduceable setup consists of an Oculus Rift, a popular low cost HMD as an immersive display as well as a Razor Hydra as a low cost 6DOF input device. Interaction space is limited with this setup and the visual quality is slightly degraded compared to the CAVE setup, but the system is highly portable and can be setup nearly anywhere.

4.2.2 Software Components

The virtual world client of the Senseparation installation is a C++ application which uses OpenSG [10] as scene graph in order to support cluster as well as server systems. VRPN (Virtual Reality Peripheral Network) [12] is for tracking purposes and allows to abstract the gathered input from the input devices. Both libraries are designed not only cross platform but also support a variety of possible input devices and displays.
The virtual environment is loaded in form of a textured VRML model [3] which has been initially created in 3D Studio Max, due to the limitations of VRML as an interchange format, lighting situations are static and have to be stored in the texture.
The avatar representation as well as dynamics of the scene are implemented fully inside the application. Simple transformations like rotations inside a transformation stack are used to create a whirlwind like appearance. In case the avatar is touched with the input device, the cubes pulsation is implemented by

simple scaling based on sinus curves.
The navigation in the virtual world is limited to navigation inside a plane, in order to reduce complexity and focus on the actual interaction. The user determines the direction by point with the input device and moves using, a button from the wand.

5 Credits

Senseparation is an interdisciplinary project of the University of Art and Design Linz (UfG), Ludwig-Maximilians-University Munich (LMU) and the Leibniz Supercomputing Centre (LRZ), in collaboration with participants from the Johannes Kepler University Linz (JKU) and the Technical University Munich (TUM).

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A Component Description

The technical setup for the Senseparation application consists of two main locations, the dark room and the virtual world environment, containing several subcomponents each.

A.1 Dark Room

A.1.1 Room

- Dimensions should be at least 3,00 x 3,50m
- Has to be completely dark
- **Alternative:** Darkened goggles could be used

A.1.2 Network Connection

- Fixed wired cable connection is required, to guarantee required bandwidth
- The IP address provided has to be fixed
- Several ports have to be opened to the specific IP to allow interconnection to the Virtual World environment

A.1.3 Audio System

- To provide spatial audio 4 speakers are needed
- 4 Stands (height approximately 120 – 160 cm) are required to position speakers in room
- Alternatively the speakers could be ceiling mounted

A.1.4 Tracking System

- For tracking currently a Kinect is used. It has to be of the type Xbox Kinect, which has to be attached via cable to the dark room PC.
- Stand for the Kinect

A.1.5 Vest

- Vest controller communicates via the Bluetooth protocol with the dark room PC

A.1.6 PC/Laptop driving the tracking system, the audio system, the vest and connecting them to the network.

- The system should ideal be placed outside the dark room
- Generate low noise
- Provide a Bluetooth interface to connect to the vest
- ASIO compatible 4-channel sound card
- Provide a screen and input devices like keyboard and mouse for configuration

A.1.7 Video Streaming (optional)

- An additional infrared camera
- Stand or ceiling mount for camera
- Streaming PC with wired network connection and display outside the dark room

A.2 Virtual World

A.2.1 Network connection

- Fixed wired cable connection is required, to guarantee required bandwidth
- The IP address provided has to be fixed
- Several ports have to be opened to the specific IP to allow interconnection to the dark room

A.2.2 Display

- Stereoscopic display supporting Quadbuffered OpenGL.
- **Alternative A:** Ideally a CAVE-like environment, could be as well a Powerwall or an alternative installation
- **Alternative B:** An Oculus Rift can be used as a display

A.2.3 Tracking System

- **Alternative A:** Ideally a 6DOF optical tracking system is used
- **Alternative B:** Inertial integrated in the Oculus Rift is possible as well

A.2.4 Input Device

- **Alternative A:** Ideally a 6DOF Wand tracked by an optical tracking system is used
- **Alternative B:** For the Oculus Rift setup a Razor Hydra could be used, with integrated magnetic tracking

A.2.5 PC/Laptop/Server/Cluster driving Display and input device and connecting them to the network.

- Provide a screen and input devices like keyboard and mouse for configuration

A.2.6 Video Streaming (optional)

- An additional camera
- Stand or ceiling mount for camera
- Streaming PC with wired network connection and display

B Component Checklist

Component	Sub component	Comment	Check?
Dark Room			
Network Component	Wired Connection Fixed IP Set Open Ports to given IP		
Audio System	4 Speakers 4 Stands 4 Audio cables (7m, 4m, 4m, 2m)		
Tracking System	Xbox Kinect Stand for Kinect	Important that an Xbox Kinect is used not a Kinect for Windows	
Vest		Will be provided by Senseparation	
PC/Laptop	Mouse Keyboard Screen Bluetooth Interface Wired Network Interface ASIO compatible 4-channel Audio Card		
Room	Size 3,00 x 3,50 Completely dark Barrier to constrain user in tracked area	 four sides with each 3m length	
Video Streaming	Infrared camera Stand or ceiling fixation for camera PC with 2 displays and network card	Optional, but adds significantly to the experience Display(s) should be mounted on the wall for visitors or have a VESA mount and an appropriate stand.	
Virtual World			
Network Component	Wired Connection Fixed IP Set Open Ports to given IP		
Display	CAVE Powerwall HMD	The display options are alternatives, a CAVE is ideal	
Input	6DOF Tracking		
PC/Laptop	Mouse Keyboard Screen Wired Network Interface		
Video Streaming	Infrared camera Stand or ceiling fixation for camera PC with 2 displays and network card	Optional, but adds significantly to the experience Display(s) should be mounted on the wall for visitors or have a VESA mount and an appropriate stand.	

C Dark Room Setup

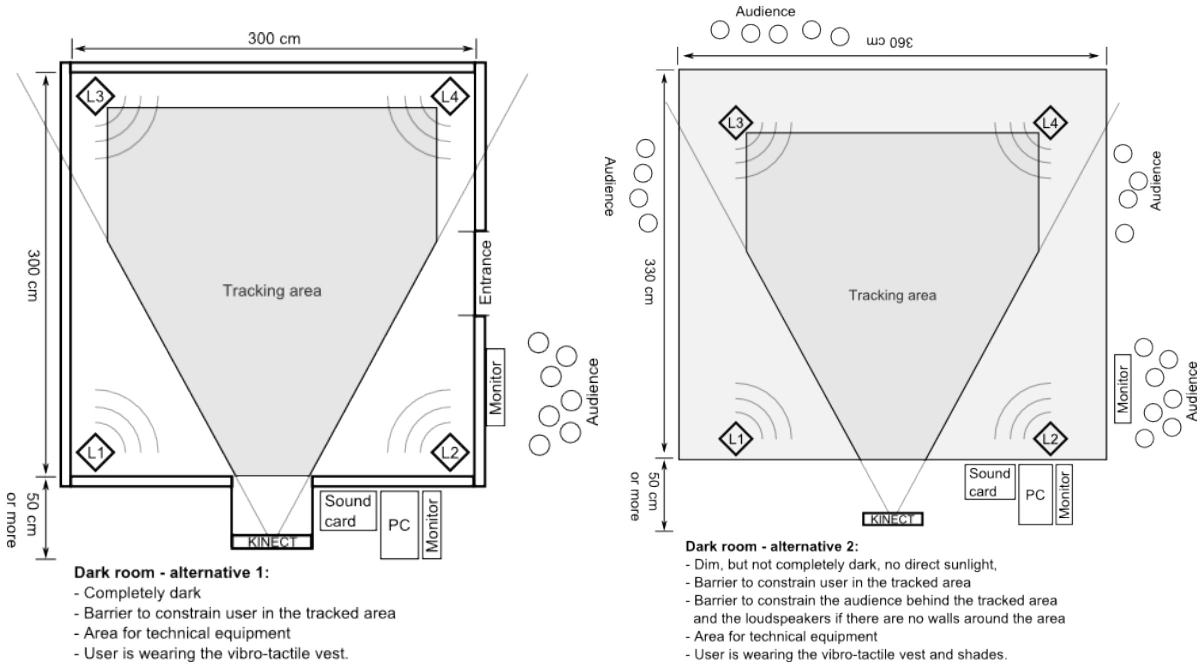

Figure 6: Floor plan of the dark room with alternative 1, competently darkened room (left) and alternative 2 user with goggles (right).

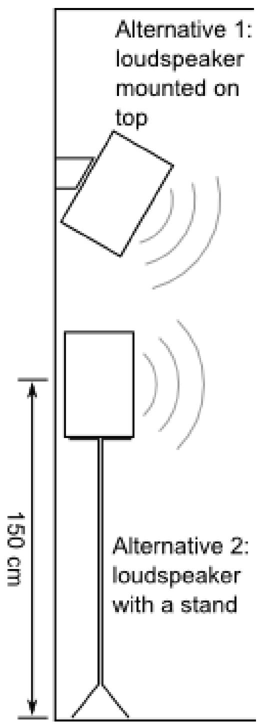

Figure 7: Installation alternatives of speakers

D VR Installation Setup

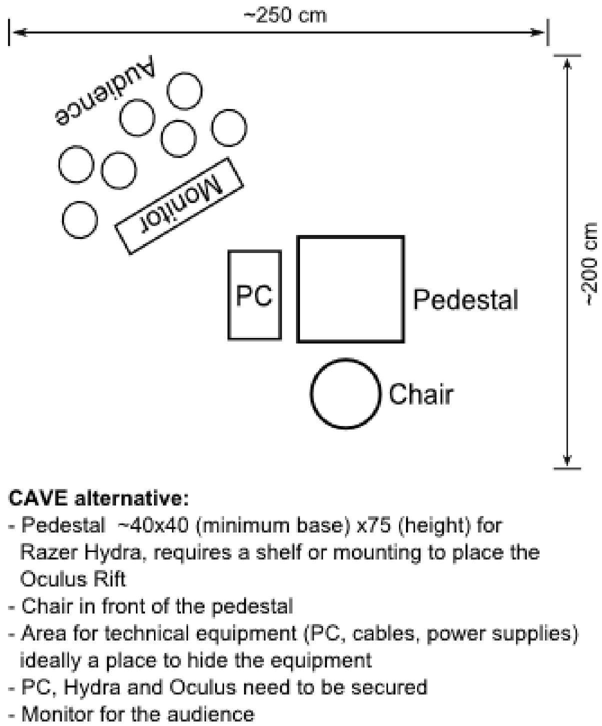

Figure 8: Floor plan of the VR Installation using a Hydra and an Oculus

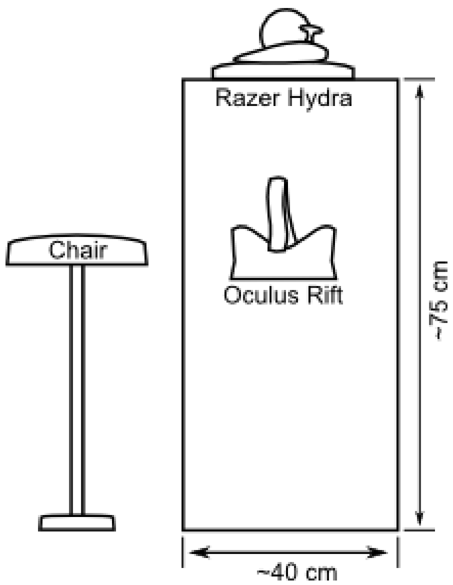

Figure 9: VR Installation using a Hydra and an Oculus (side view)