

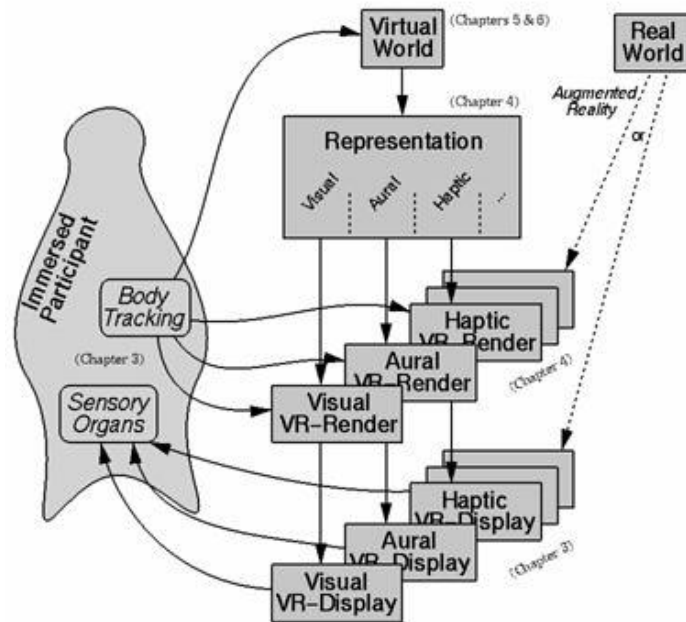


Virtual Reality & Augmented Reality

A/Prof Manolya Kavakli
Department of Computing
Macquarie University
Sydney, Australia

Future of VR

- <http://www.youtube.com/watch?v=bBjvqnKQsTI&list=PLDF1BBECCE066EE5E>



Virtual Reality

Jaron Lanier (1989)

- *a medium composed of interactive computer simulations*
 - *sense the participant's position and*
 - *replace or augment the feedback to one or more senses*
 - *giving the feeling of*
 - *being immersed or*
 - *being present in the simulation.*





A VR system induces
a sense of presence and
a sense of immersion
in the virtual world
(Marsh et al. 1998).

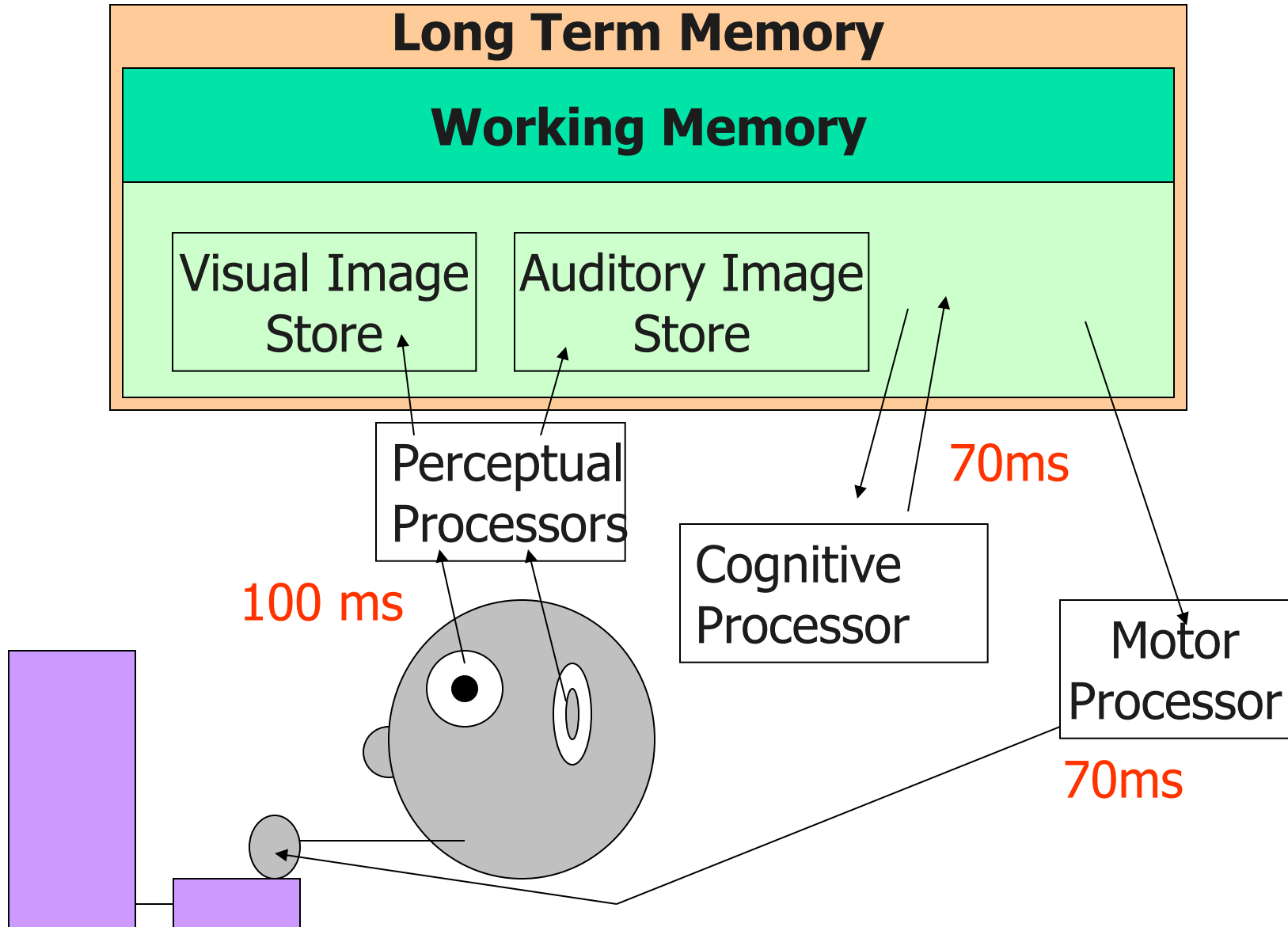


Characteristics of VR

- Immersion / Visualization:
 - Immersion is maintained at least in one sensory modality (vision)
 - The computer generating visual, auditory or other sensual outputs to the user of a world within the computer.
- Interaction:
 - The user can interact with this virtual world, directly manipulating objects in it.



The Model Human Information Processor



Perceptual Processor

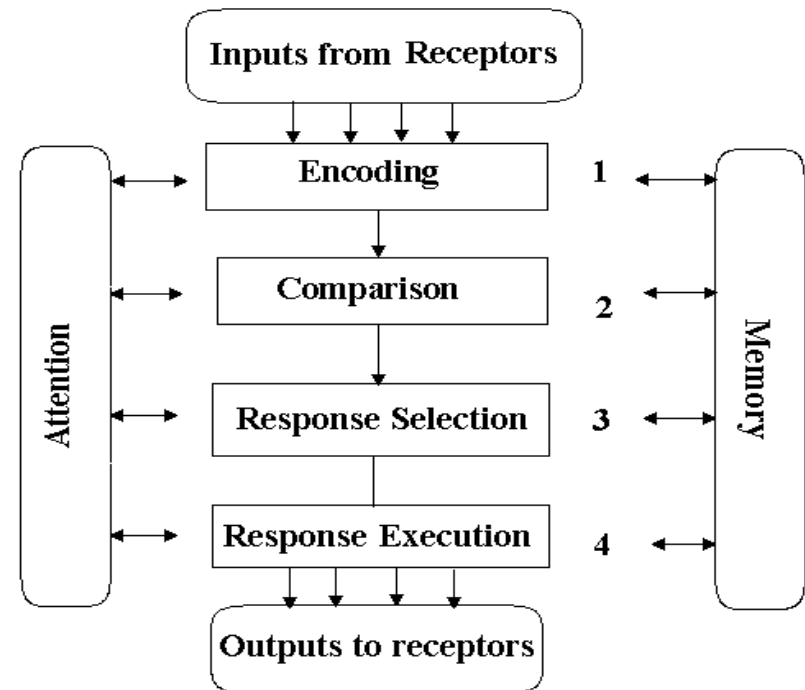
- The speed of the perceptual processor:
~100ms per cycle
 - Light blinks appearing within 100ms
 - look like a single brighter light
 - Light blinks in two locations within 100ms
 - look like motion of a single light
 - Auditory clicks occurring within 100ms
 - sound like one louder tone
 - Multiple taps occurring within 100ms
 - feel like one tap of greater pressure

Putting It All Together

- Simple reaction time
 - 1 perceptual cycle + 1 cognitive cycle + 1 motor cycle
 - $100\text{ms} + 70\text{ms} + 70\text{ms} = 240\text{ms}$
- Physical match
 - 1 perceptual cycle + 2 cognitive cycles + 1 motor cycle
 - $100\text{ms} + 70\text{ms} + 70\text{ms} + 70\text{ms} = 310\text{ms}$

Stage Model of Info Processing

- Encoding –
 - information from environment into some internal representation
- Comparison –
 - internal representation with previous memorised representations
- Selection –
 - decision on appropriate response to encoded stimulus
- Execution –
 - organisation of response into action



The Stoop Effect

- Demonstrates automatic processing
- Shows how resources are limited
- In the next two slides –
- say the color of the letters
 - XYJFI – say “Red”
 - HQOP – say “Green”
- I’ll time you



JCRTS

PJYTD

MCDRI

SQUR

PHENC

WFUB

YSCOP

YSVIE

SFTOW

OGSLEY



GREEN

BLUE

YELLOW

RED

YELLOW

GREEN

BLUE

GREEN

YELLOW

RED

'Virtual Reality' (VR)

- The term coined by Jaron Lanier (1989).
- related terms:
 - 'Artificial Reality' (Myron Krueger, 1970s),
 - 'Cyberspace' (William Gibson, 1984),
 - 'Virtual Worlds' and 'Virtual Environments' (1990s).
- Today, 'Virtual Reality' is used in a variety of ways:
 - often in a confusing and misleading manner.
 - Originally, the term referred to 'Immersive Virtual Reality.'
 - In immersive VR, the user becomes fully immersed in an artificial, three-dimensional world that is completely generated by a computer.



A brief history of Link Trainer/ Blue Box



■ 1929

- After several years of flight training via "penguin" trainers
- aircraft with shortened wings.
- Edward Link develops a simple mechanical *flight simulator* to train a pilot at a stationary (indoor) location.
- The trainee can learn to fly and navigate using instruments via instrument replicas in the cockpit of the *Link Trainer*.
 - Toy aeroplane with organ bellows and an electric pump Air corps ordered 6 trainers for \$3500 each in 1934
 - Sold 10000 in WWII

■ 1968

- "A head-mounted three dimensional display,"
- Ivan Sutherland describes his development of a tracked stereoscopic head-mounted display at Harvard University.
- The display uses miniature CRTs with optics to present separate images to each eye, and is interfaced with mechanical and ultrasonic trackers.
 - Sample virtual worlds include a stick representation of a cyclohexane molecule, and a simple cubic room with directional headings on each wall.



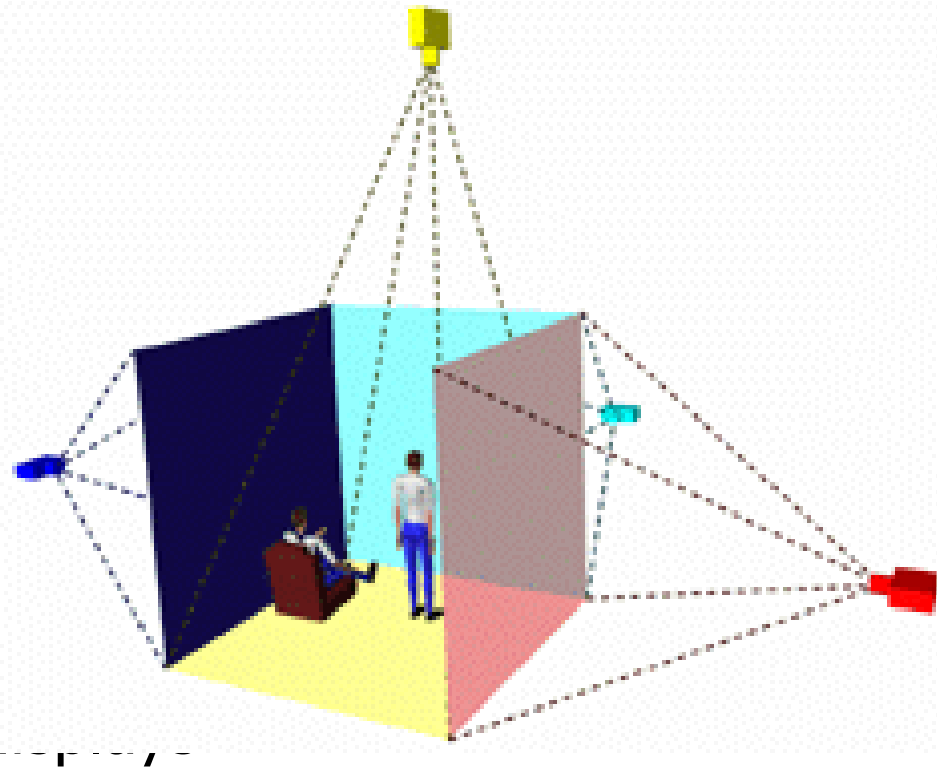


■ 1990

- W-Industries launches the first public venue VR system, coining it *Virtuality*.
- It is a dual-player VR arcade system that includes an HMD, hand-held prop, and ring platform for each participant.
- The initial game -- *Dactyl Nightmare* -- involves two players in a simple multi-level world where they attempt to shoot one another.
 - In 1993, W-Industries changes their name to Virtuality PLC, and in 1997 they sell their assets as part of filing for Chapter 11 Bankruptcy.

The CAVE

- **1991**
- Instead of using a HMD
- imagine a room
- where output of computer
- is projected onto the walls.
 - The projected images are in stereo
 - by rapidly alternating between the two eye images.
- You stand somewhere near the middle and
- wear shutter glasses for a 3D effect.
 - This concept was first developed in 1991 in Chicago
 - at the [Electronic Visualization Lab](#) of the University of Illinois.



The CAVE

(Cave Automatic Virtual Environment)

- provides the illusion of immersion by projecting stereo images on the walls and floor of a room sized cube
- (3m per side) with each wall functioning as a rear-projection screen illuminated by a projector.
 - Several persons wearing lightweight stereo glasses can enter and walk freely inside the CAVE.
 - A head tracking system continuously adjust the stereo projection to the current position of the leading viewer.
- A mainframe drives all of the CAVE's projectors, displaying a contiguous visual image across all screens to produce a virtual landscape.
 - Stereographic imaging makes the virtual objects look more three-dimensional,
 - while real-time spatial tracking lets users interact with the objects and navigate the space.

CAVE @ ENSAM, Chalon Sur Saone, France



Evolution of VR systems

- Throughout the 1990s,
- researchers developed many VR applications for the CAVE and similar displays.
- They either programmed these applications directly,
 - starting from OpenGL or a similar graphics library,
 - or wrote them using advanced authoring kits.
- Despite the process's difficulty and expense,
- it usually produced applications with
 - poor and often primitive graphics,
 - low performance, and
 - limited networking functionality.



- In 1997,
- Paul Radjlich produced
- a version of *Quake* for CAVE
- that inherited the game's authoring support, networking, and other features.
 - Unfortunately, Cave-Quake could not benefit from *Quake's* game engine, which was PC-based.

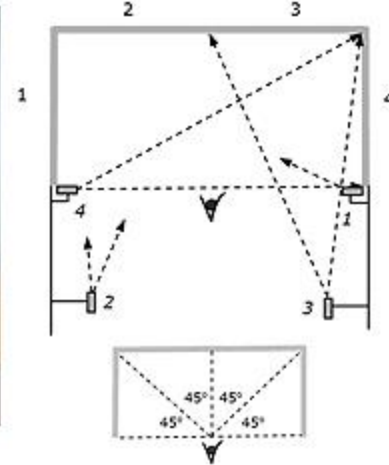




■ 1998

- *Disney* opens the first of their
- *DisneyQuest* family arcade centers
 - which feature numerous VR attractions using both HMD, and projection-based visual displays.

By 2000



- the game industry has driven significant advances in graphics hardware for the PC, and
- CAVE owners began replacing their mainframes with PC networks.
- Further, the leading first-person shooters,
 - *Quake* and
 - *Unreal Tournament*,
- surpassed the traditional CAVE-based applications in graphics quality, performance, animation, and networking.
 - These games also had respectable authoring support, built-in physics, partially open source code, a large base of existing content, and an active developer community.

in 2000

- *Unreal Tournament*
- was adapted to the BNAVE,
 - a PC-based CAVE-like display.
- Michael Lewis, Jeffrey Jacobson and Jimmy Hwang invested a year of careful study,
 - then solved the multiscreen display problem by inserting just six lines into the game's open source code.
- the first version of CaveUT,
- a freeware project to attract collaborators.
 - Today, most software development for CAVE still uses the traditional VR authoring tools, which have improved considerably but remain expensive.



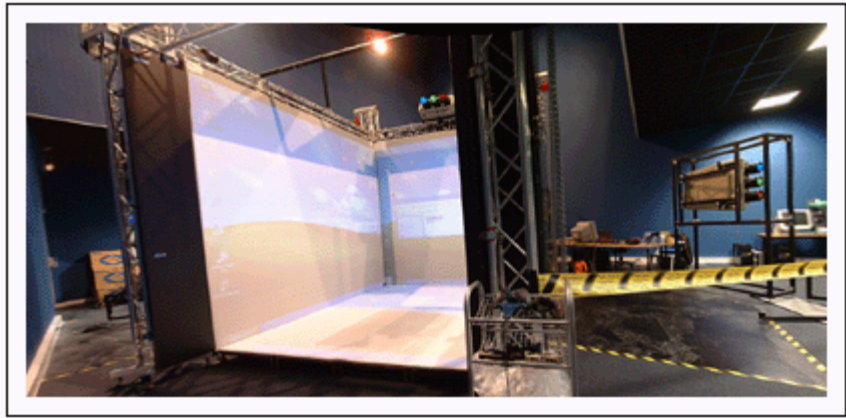


BNAVE: Balance NAVE

Automatic Virtual Environment

- The centerpiece of the MVRC is a spatially-immersive display setting called the.
- This structure was modeled after the NAVE at Georgia Tech University.
- A virtual environment is displayed seamlessly across 3 vertical screens and a floor screen surrounding the subject, resulting in a field of view of 180° horizontally and 110° vertically.
- The continuous environment is coordinated by PCs that communicate through a LAN.

Bnave



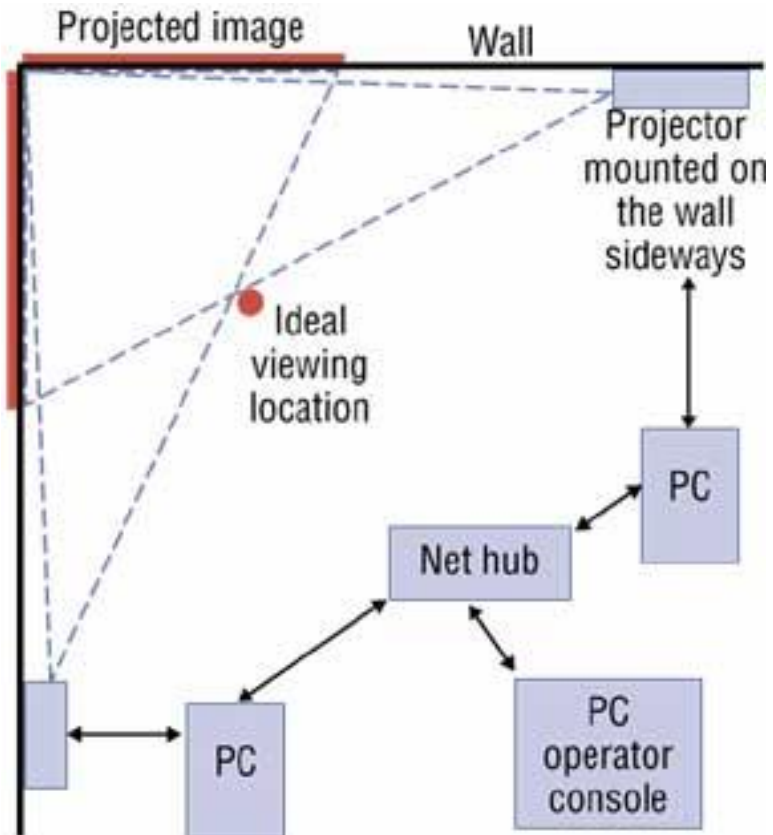
LAVAL France by Cavazza

- CaveUT was originally developed on the BNAVE, a PC-based CAVE-like display the Medical Virtual Reality Center, Department of Otolaryngology, University of Pittsburgh.

A multiscreen display based on CaveUT that requires

- a server computer
 - that connects by a standard LAN
 - to several client computers.
- Each client drives one screen of the display,
- usually a projection screen
- illuminated by a digital projector.

V-Cave



- To handle perspective correction,
- CaveUT employs Willem de Jonge's VRGL,
- an OpenGL library modified for VR applications.
 - For an installation with no head tracking,
 - the user must specify a single ideal viewing location for the whole display.
 - As long as the user's head stays at or very near this point, the view will remain unified and undistorted.
 - If the installation does have a head tracker,
 - CaveUT can correct the perspective in real time to effectively follow the user's movement.

- CaveUT, an open source freeware project,
- uses game technology to make immersive projection-based virtual reality affordable and accessible.
- Relatively simple, the current public release of CaveUT works well for low-cost displays.
- supports real-time spatial tracking and stereographic imaging.
- It is currently installed and working in the SAS-Cube, a CAVE-like display.
- CaveUT modifies *Unreal Tournament*
 - to let it display in multiscreen enclosures suitable for immersive virtual reality applications.
- VR applications developed with CaveUT inherit
 - all the Unreal Engine's capabilities
 - along with *Unreal Tournament*'s authoring support,
 - open source code,
 - content library, and
 - large user community.

Game engines

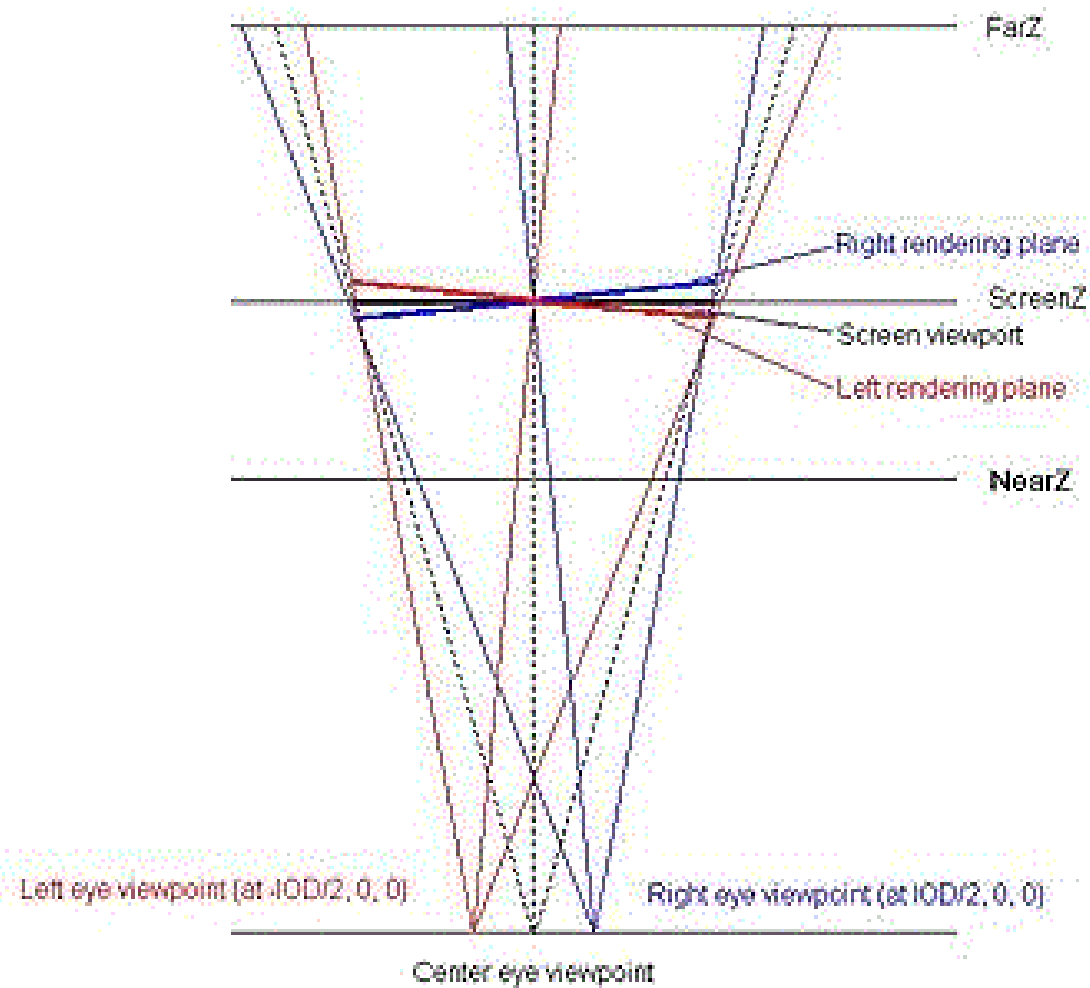
- Computer games with the most advanced simulation and graphics usually employ a *game engine*, a commercially available software package that handles basic functions.
- For example, the first-person shooter *Unreal Tournament* for the PC employs the Unreal Engine to provide
 - richly detailed graphics,
 - high-speed processing performance,
 - a built-in physics engine,
 - a scripting language interpreter, and
 - robust networking for shared environments.

How 3D effects work

- Our ability to see stereo-vision comes from each of our eyes seeing a slightly different view of the world.
- Our brain integrates these two images into one three-dimensional picture.
- The key element in producing the stereoscopic depth effect is parallax.
 - Parallax is the horizontal distance between corresponding left and right image points.
 - The stereoscopic image is composed of two images generated from two related perspective viewpoints, and the viewpoints are responsible for the parallax content of a view.

Quad-buffering

- Quad-buffering is the ability to render into left and right front and back buffers independently.
- The front left and front right buffers displaying the stereo images can be swapped in sync with shutter glasses while the back left and back right buffers are being updated –
- giving a smooth stereoscopic display.



```
//toed-in stereo

float depthZ = -10.0; //depth of the object drawing

double fovy = 45; //field of view in y-axis
double aspect = double(screenwidth)/double(screenheight); //screen aspect ratio
double nearZ = 3.0; //near clipping plane
double farZ = 30.0; //far clipping plane
double screenZ = 10.0; //screen projection plane
double IOD = 0.5; //intraocular distance

void init(void)
{
    glViewport (0, 0, screenwidth, screenheight); //sets drawing viewport
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluPerspective(fovy, aspect, nearZ, farZ); //sets frustum using gluPerspective
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
}

GLvoid display(GLvoid)
{
    glDrawBuffer(GL_BACK); //draw into both back buffers
    glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT); //clear color and depth buffers

    glDrawBuffer(GL_BACK_LEFT); //draw into back left buffer
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity(); //reset modelview matrix
    gluLookAt (-IOD/2, //set camera position x=-IOD/2
               0.0, // y=0.0
               0.0, // z=0.0
               0.0, //set camera "look at" x=0.0
               0.0, // y=0.0
               screenZ, // z=screenplane
               0.0, //set camera up vector x=0.0
               1.0, // y=1.0
               0.0); // z=0.0
```

```

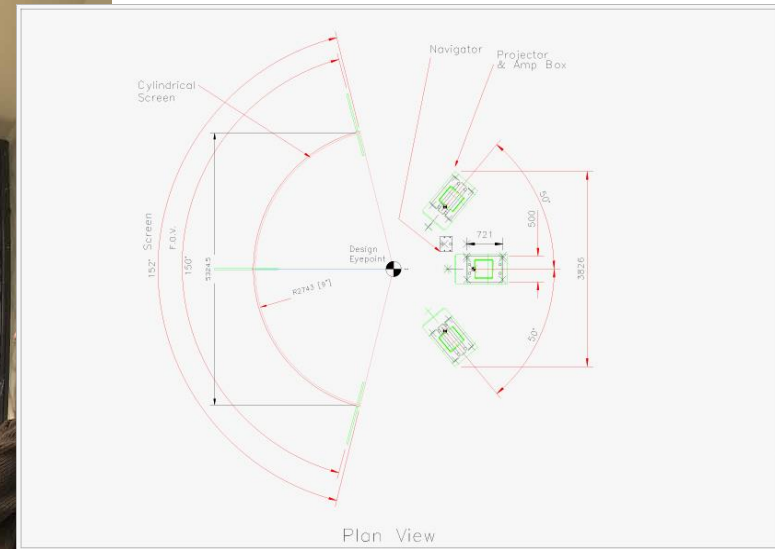
glPushMatrix();
{
    glTranslatef(0.0, 0.0, depthZ);           //translate to screenplane
    drawscene();
}
glPopMatrix();

glDrawBuffer(GL_BACK_RIGHT);                //draw into back right buffer
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();                          //reset modelview matrix
gluLookAt(IOD/2, 0.0, 0.0, 0.0, 0.0, screenZ, //as for left buffer with camera position at:
          0.0, 1.0, 0.0);                  //              (IOD/2, 0.0, 0.0)

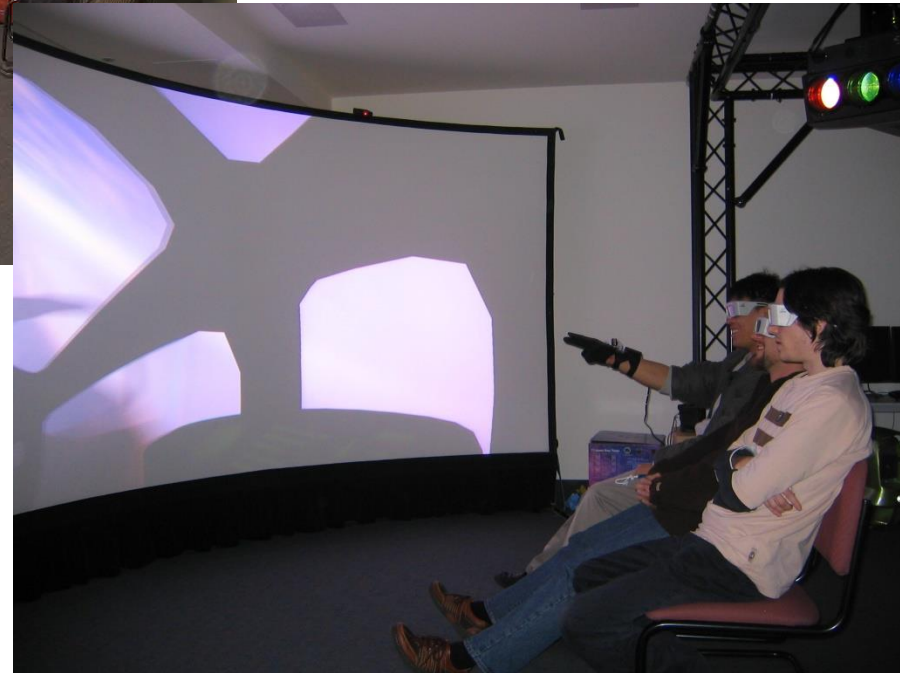
glPushMatrix();
{
    glTranslatef(0.0, 0.0, depthZ);           //translate to screenplane
    drawscene();
}
glPopMatrix();

glutSwapBuffers();
}

```



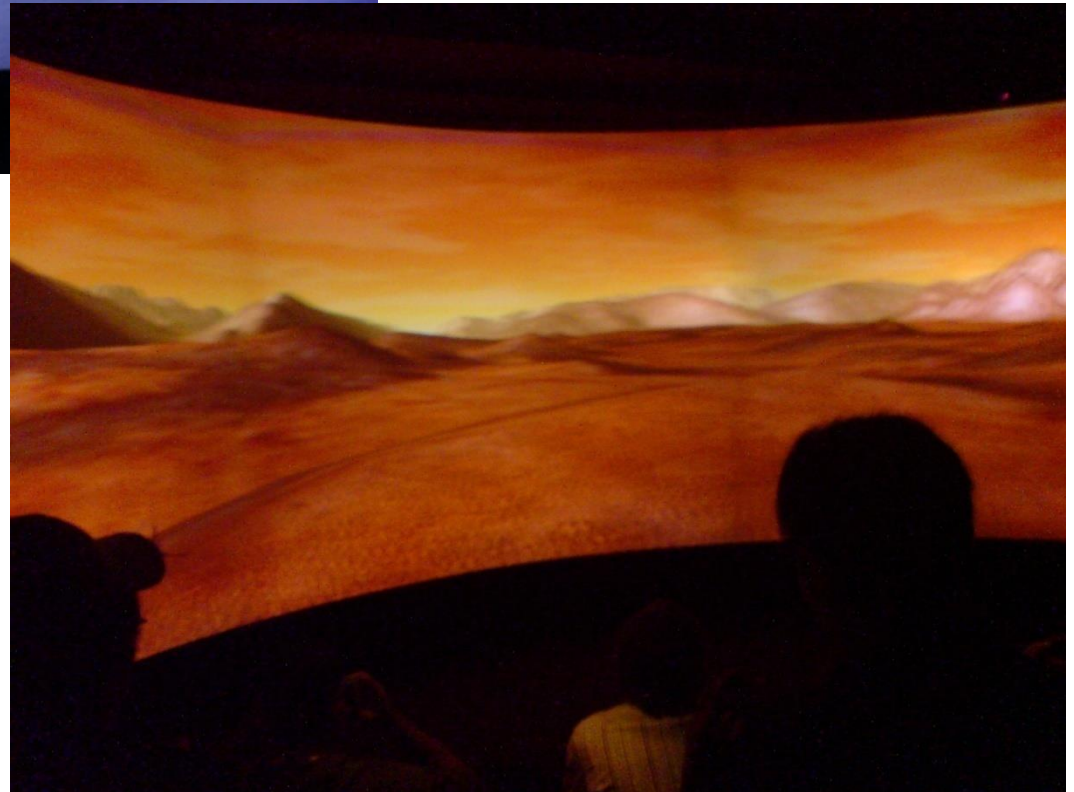
The immersive projection system (VISOR) consists of three projectors which display the virtual world onto a 6m wide semi-cylindrical screen canvas



VisoR: Virtual and
Interactive Simulation
of Reality Research
Group 2008

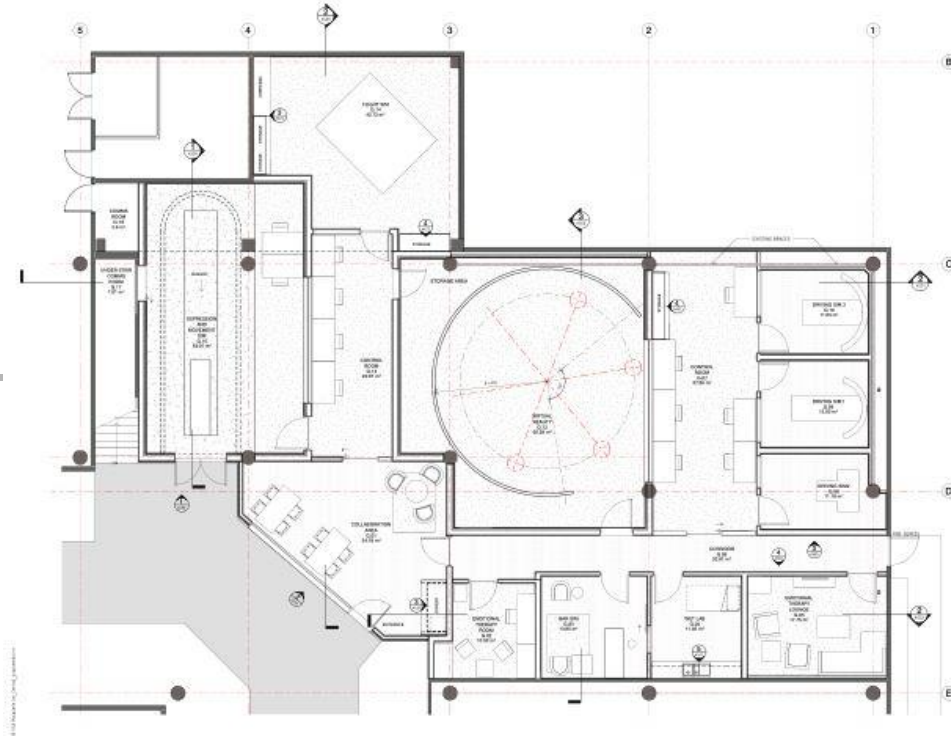


- The digital content, created in Blender, was integrated into Vizard VR Toolkit including a Python scripting language.



VisoR: Virtual and
Interactive Simulation
of Reality Research
Group 2008

MQ Sim Hub VR Lab



Projector technology

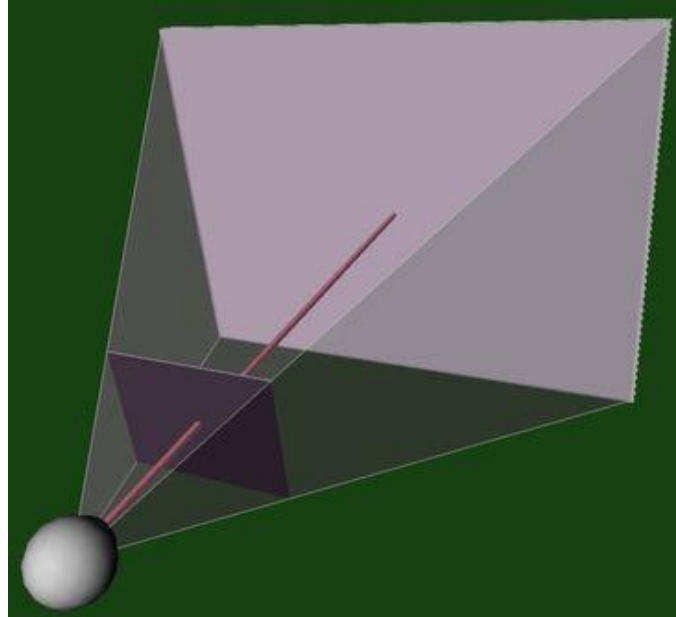
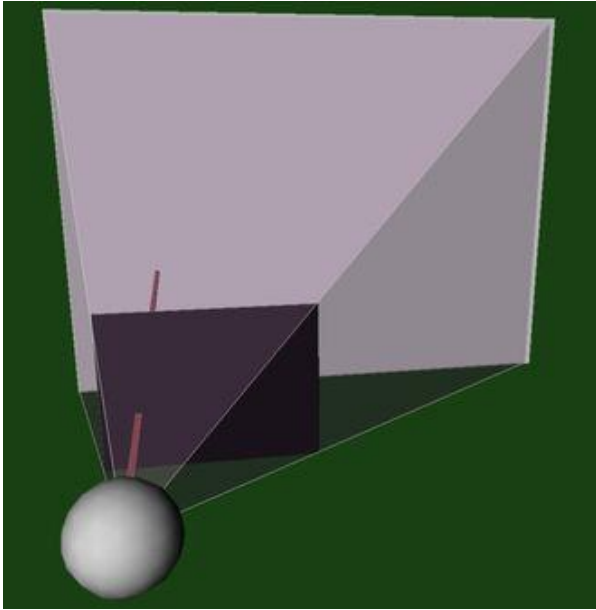


- Front projection:
 - there are two main alternatives:
 - the first is to slightly rotate the projectors so their images overlap (one projector mounted above the other),
 - the other is mount the projectors horizontally and clip the top and bottom of the images appropriately.
- Rear projection:
 - fixed lens shift is fine,
 - one projector is on the floor and the other on the ceiling.

Projectors

- There are numerous projector technologies available.
- CRT projectors:
 - generally bulky, hard to calibrate, have a low light output, and offer no significant benefits for passive stereo.
- LCD projectors:
 - problematic because their light is already partially polarised.
 - While there are ways to compensate for this it is generally considered too messy and often requires one to manufacture their own glasses since the filters end up at non standard angles (usually ± 45 degrees).
- DLP projectors:
 - suitable, they produce unpolarised light, are bright, and can come in small packages.

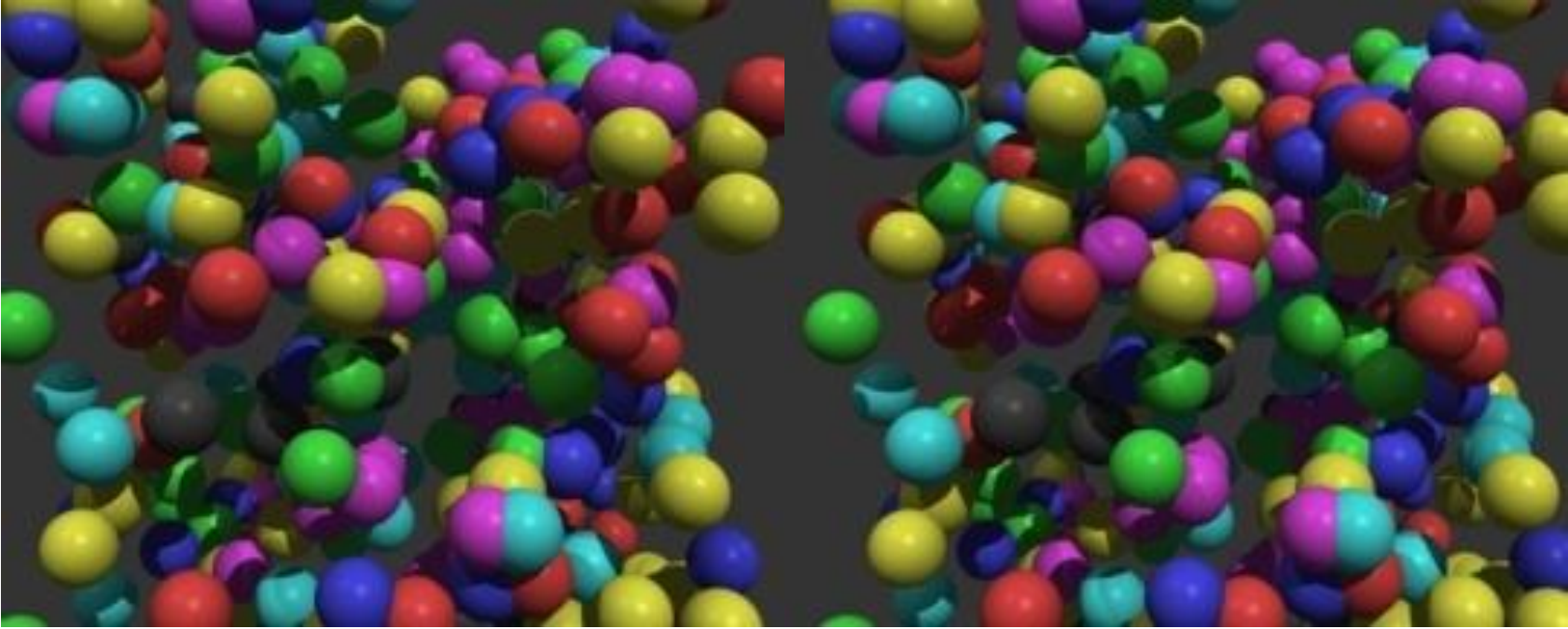
Active and Passive Stereo



- Presentation of stereographic images:
 - active and passive stereo.
 - Both of these methods use eye-wear,
 - "active" refers to glasses with electronic components,
 - "passive" refers to no electronics.

How 3D displays work

- Electro-stereoscopic displays provide
 - parallax information to the eye by using a method
 - related to that employed in the stereoscope.
-
- The 3D display systems normally in use use one of the following methods:
 - ⑩ Separate display for each eye (used in HMDs)
 - ⑩ Shutter glasses (most common method)
 - ⑩ Color filter glasses (used in some old 3D movies)
 - ⑩ Polarizing glasses (used in some modern 3D movies)



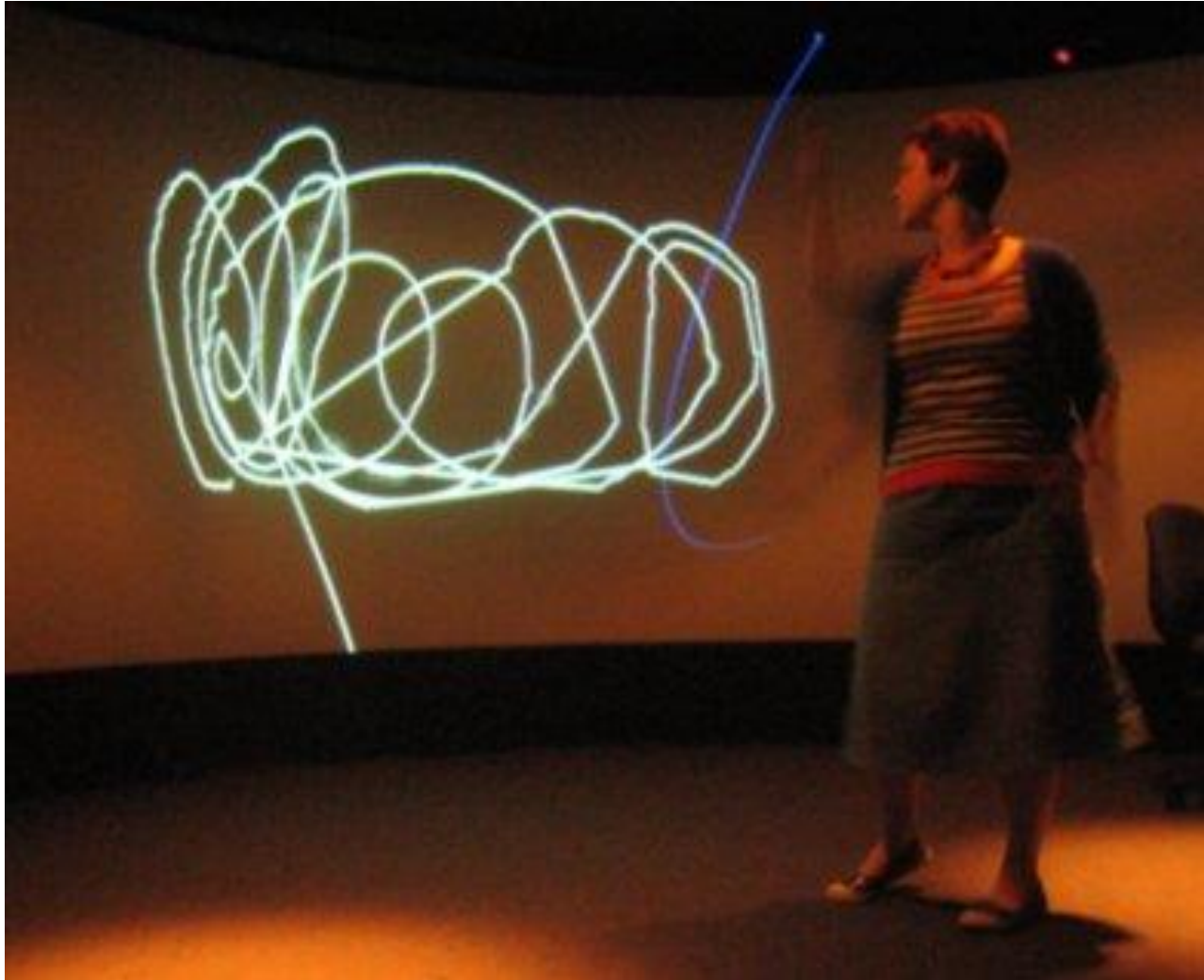
■ *Figure : A Stereo Pair of Images*

- Cross your eyes so that the two images overlap as one image in the center.
 - This may be easier if you move back from the page a bit.
 - After a while, your eyes will lock and re-focus on the center image. When that happens, you will see the 3D layout of the spheres pop out at you.
- Roughly $\frac{1}{3}$ of the people can see it within a minute, another $\frac{1}{3}$ can see it with practice, and the remaining $\frac{1}{3}$ seem to have a hard time.



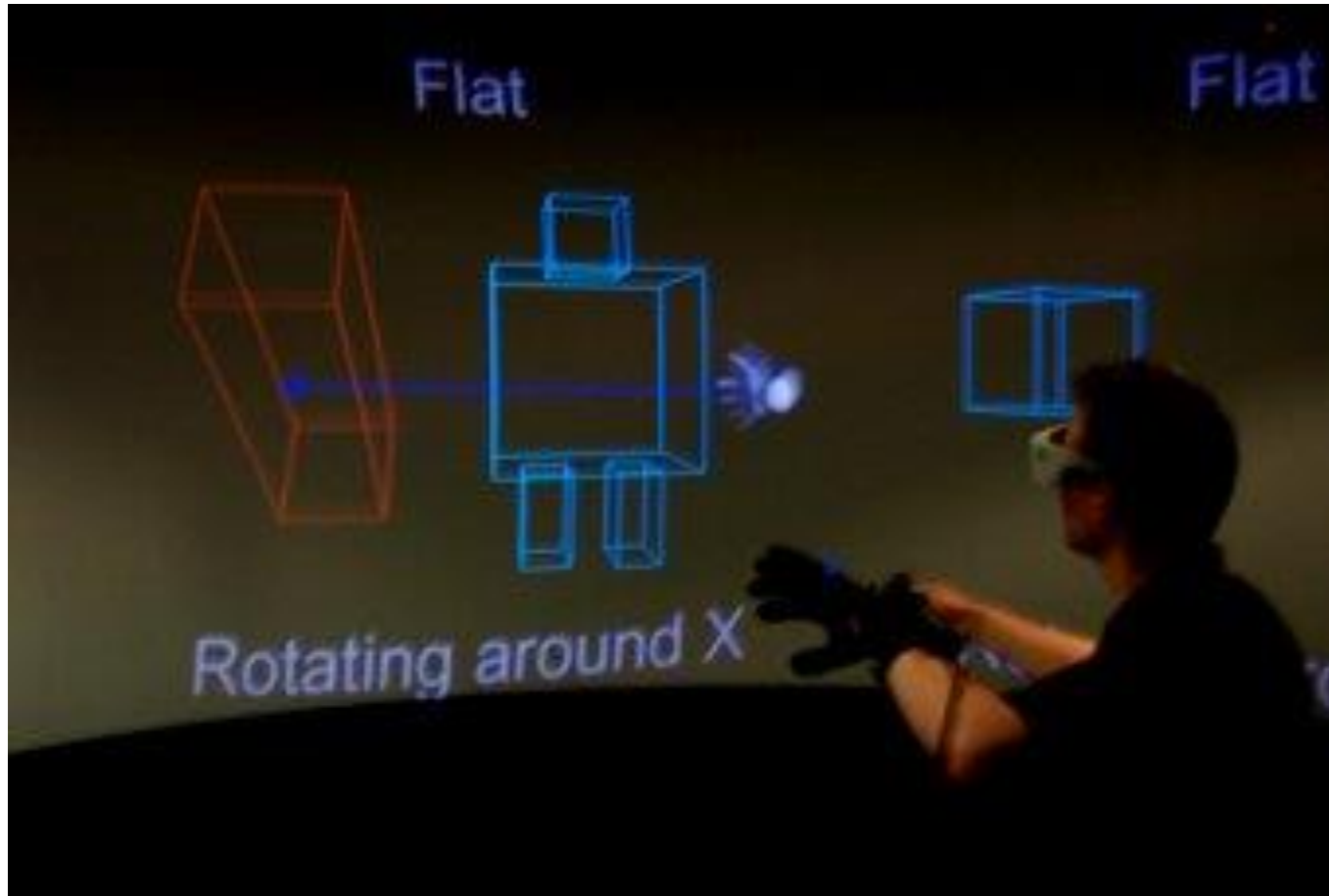


DeSIGN



VisoR: Virtual and Interactive Simulation of Reality Research Group 2008

DESIRE



VisoR: Virtual and Interactive Simulation of Reality Research Group 2008

DRive

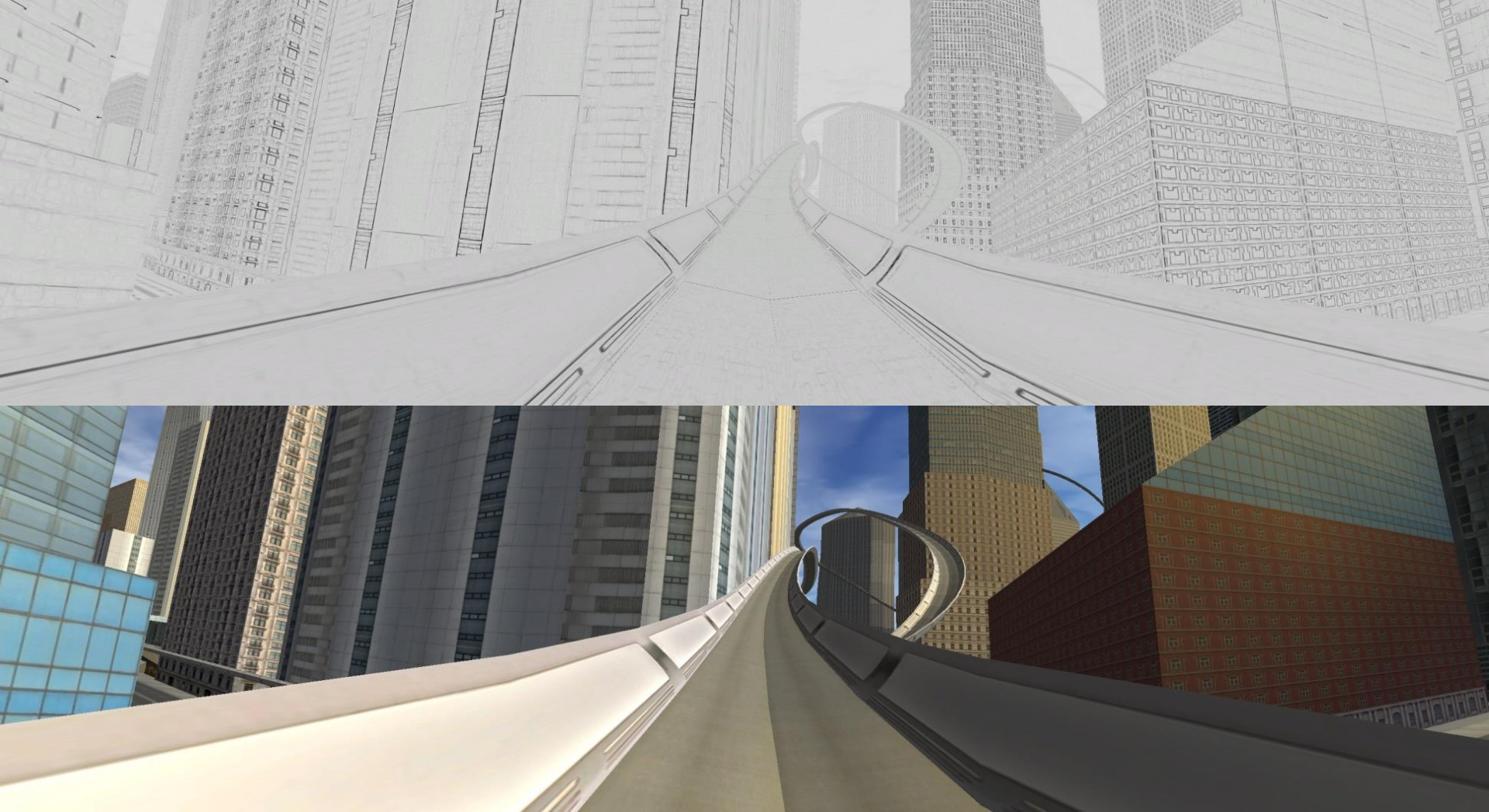


VisoR: Virtual and Interactive Simulation of Reality Research Group 2008



Complexity of Environments and Simulator Sickness



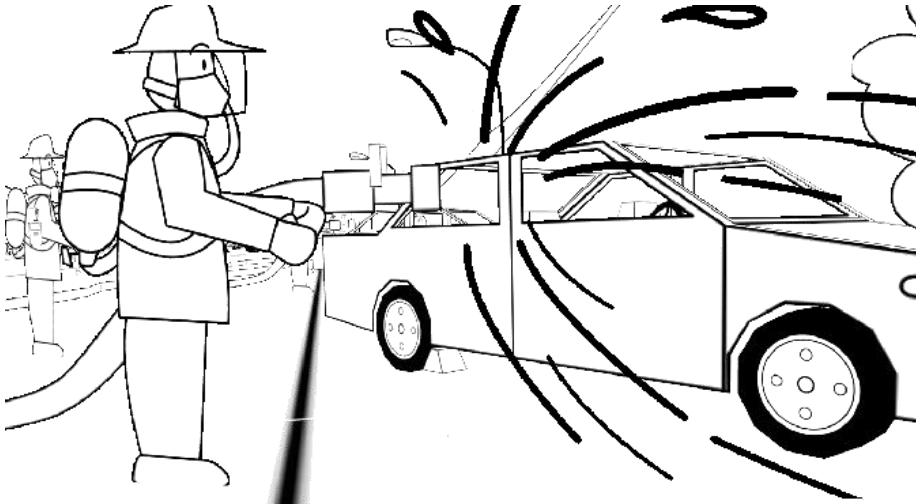


VisoR: Virtual and Interactive Simulation of Reality Research Group 2008

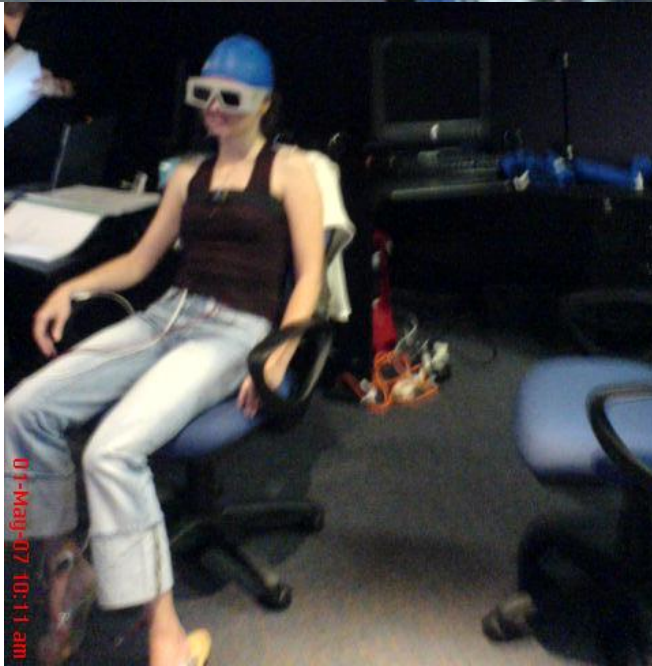
Complexity of Avatars and Learning



Complexity of Environments and Avatars and Learning



Biopack-EEG



Emotiv Headset



Data gloves



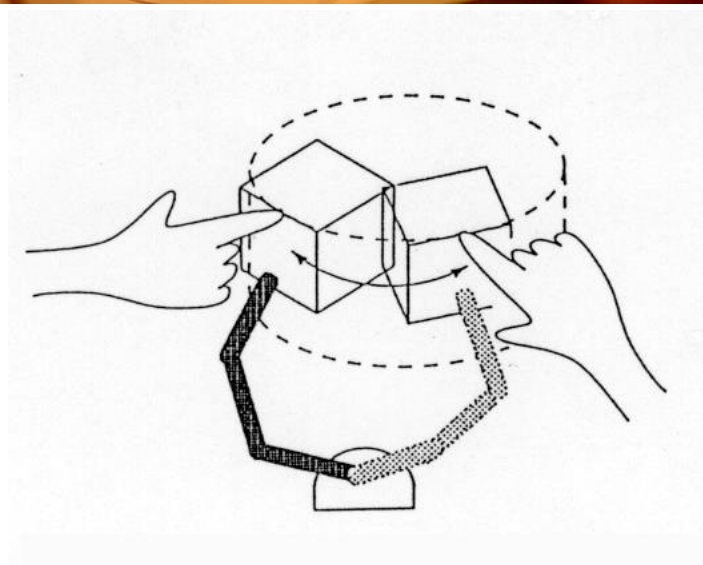
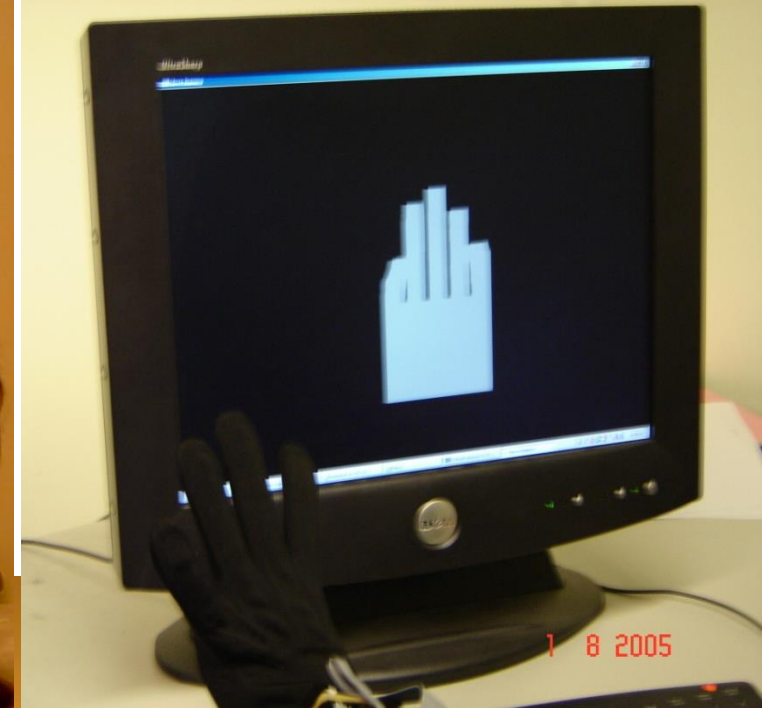
- A variety of input devices like data gloves, joysticks, and hand-held wands allow the user
 - to navigate through a virtual environment and
 - to interact with virtual objects.
- Directional sound, tactile and force feedback devices, voice recognition and other technologies are being employed to enrich the immersive experience and to create more "sensualized" interfaces.
- A data glove allows for interactions with the virtual world.

Force Feedback

(haptic feedback)

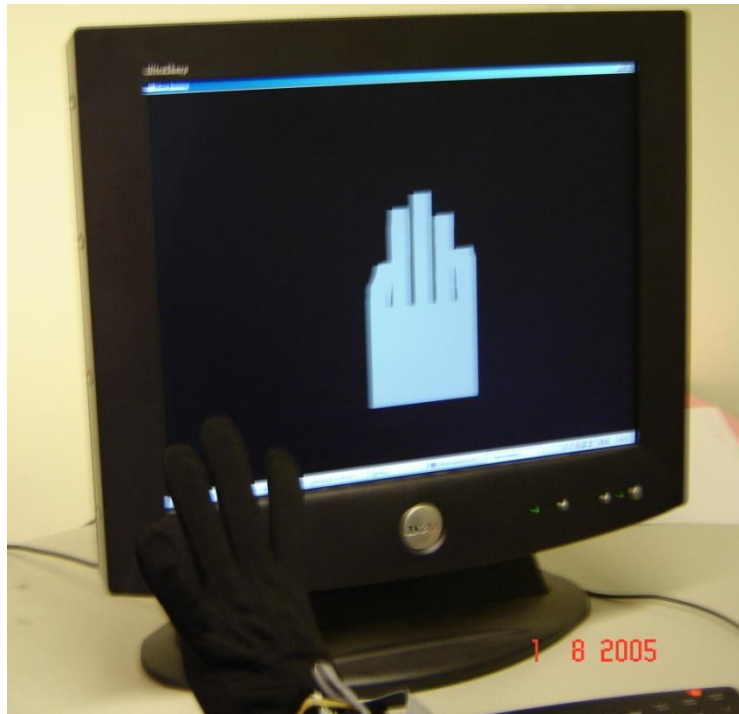
- Suppose the special glove
- could not only sense
- joint angles, but also had actuators that could push back at you.
- The actuators could present the illusion of hard objects at particular locations.
 - Note that force feedback is currently limited to "pushing back" to simulate the existence of a object. It does not provide other parts of what we call tactile feel, like texture, temperature, etc.



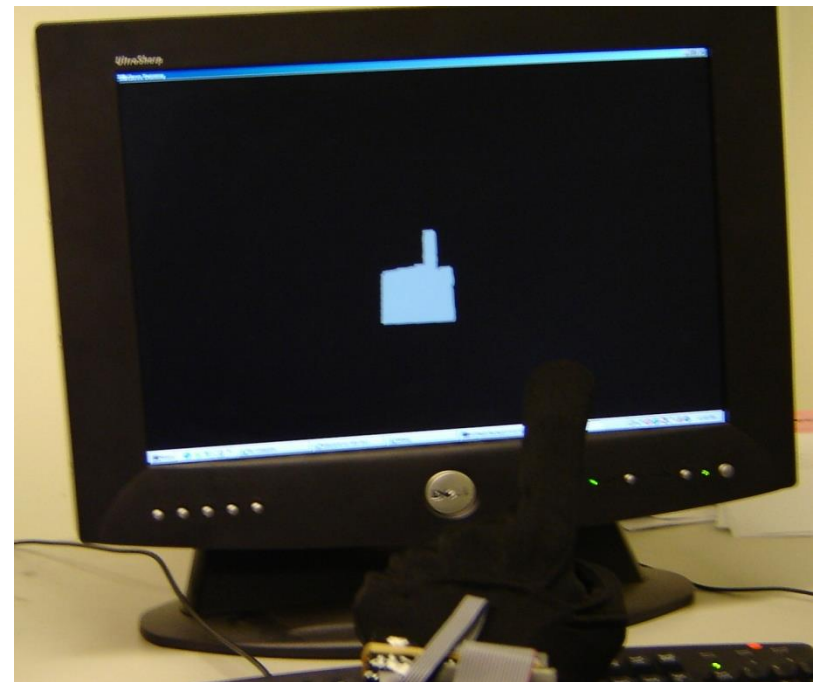


VR Hand

- Simulation of hand using the OpenGL hand model and a data glove



Open Hand



Index Finger Point

Hand gesture recognition

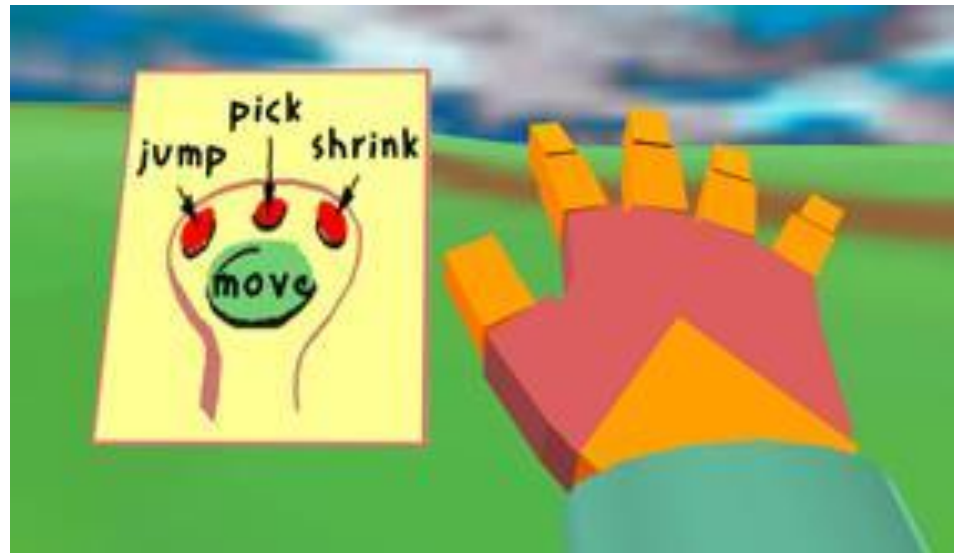
- $2^5=32$ possible combinations of gestures
- 5W:1 sensor per finger vs 16W:3 sensors
 - Zoom in and out using mouse or keyboard

Gesture		Sketching Task	Flexure value x ($0 \leq x \leq 1$)				
ID	Name		Thumb	Index	Middle	Ring	Little
0	Fist	Stop	≤ 0.1	≤ 0.1	≤ 0.1	≤ 0.1	≤ 0.1
1	Index Finger Point	Draw	≤ 0.1	≥ 0.9	≤ 0.1	≤ 0.1	≤ 0.1
2	Open Hand	Erase	≥ 0.9	≥ 0.9	≥ 0.9	≥ 0.9	≥ 0.9

Gesture Definition Table

Tracking Technology

- Electromagnetic
- Acoustic/Ultrasonic
- Mechanical
- Optical
- Inertial
- Neural/Muscular

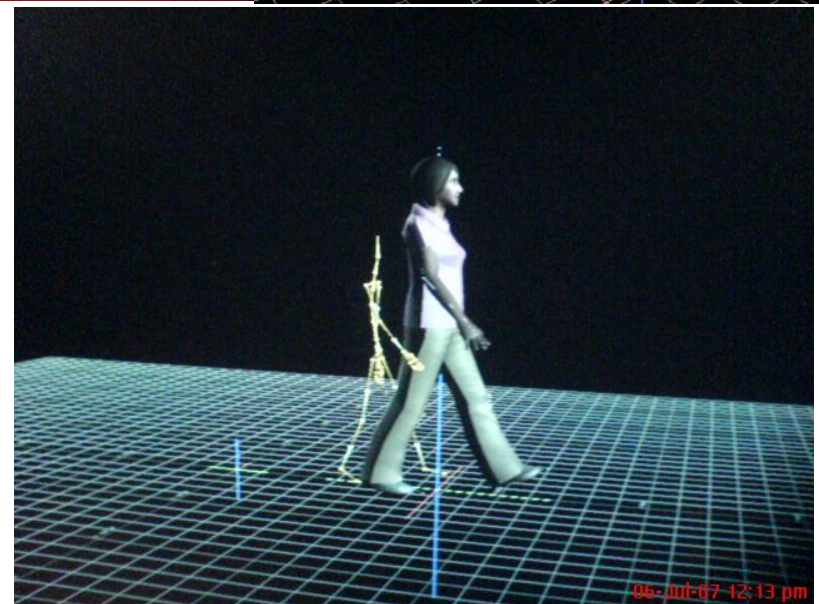
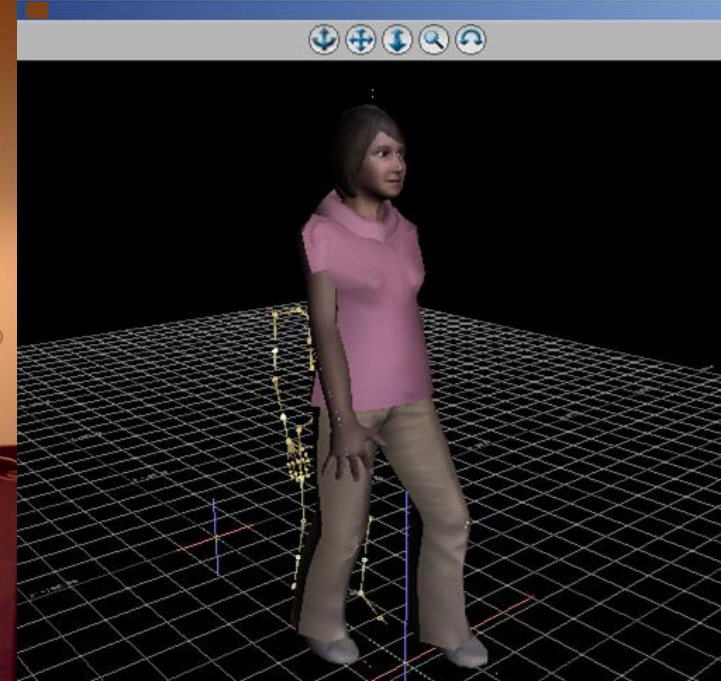


Motion capture



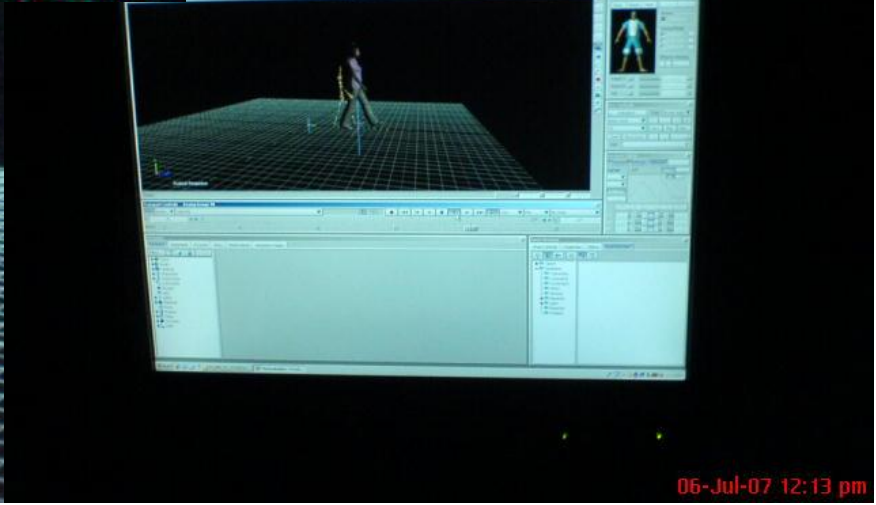
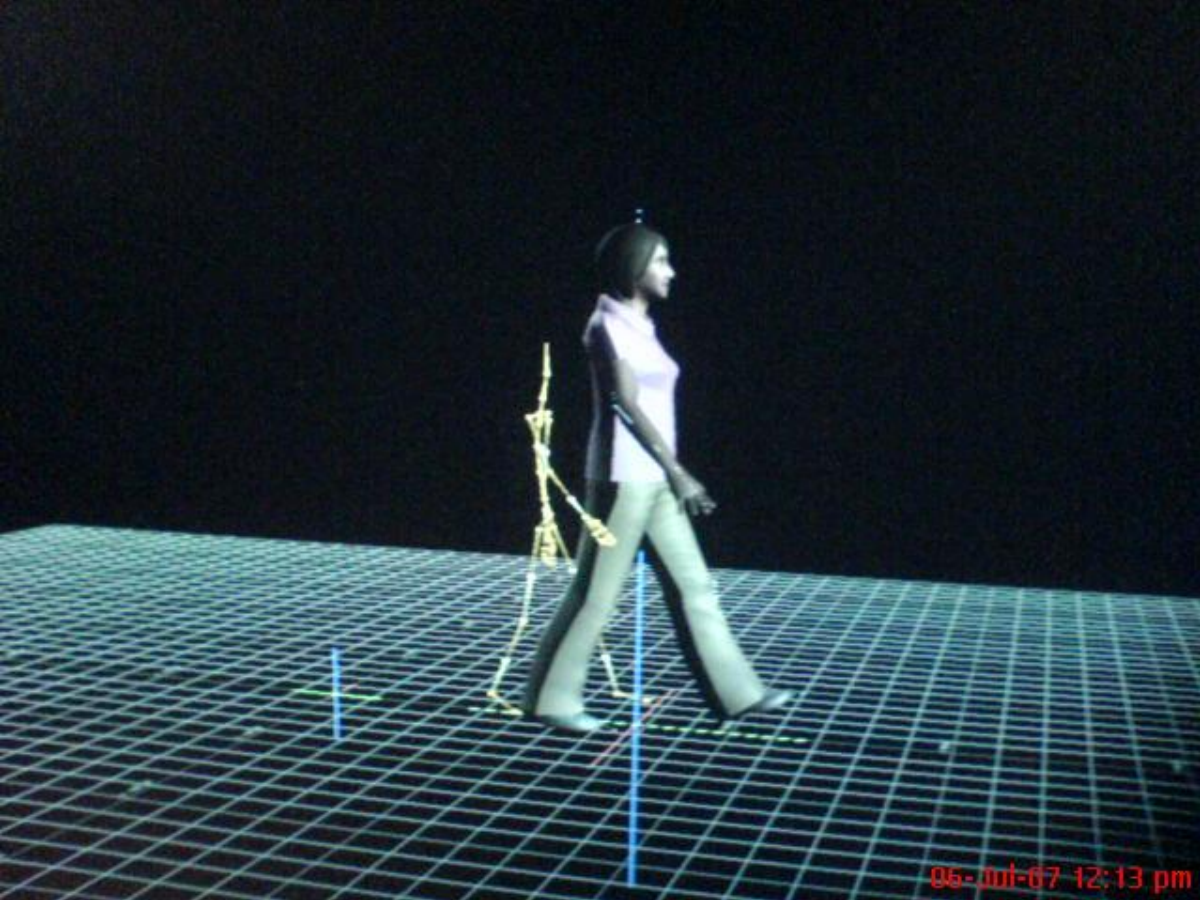
Gesture Recognition System

- We used **Softimage | XSI** for creating a 3D landscape and an airport model.
- We modified the layout of the digital world in **Blender**. We exported the digital world to Vizard file format. We used **3D Studio Max** and Softimage|XSI with FBX plug-ins for 3D modelling. 3D Studio Max has a built in exporter for .FBX format which **MotionBuilder** reads. In MotionBuilder, we set up the rig of the character and applied the Motion-Capture (mocap) animation onto the character's skeleton. The animation footage is produced by **Vizard Virtual Reality software**.





VisoR: Virtual and Interactive Simulation of Reality Research Group 2008

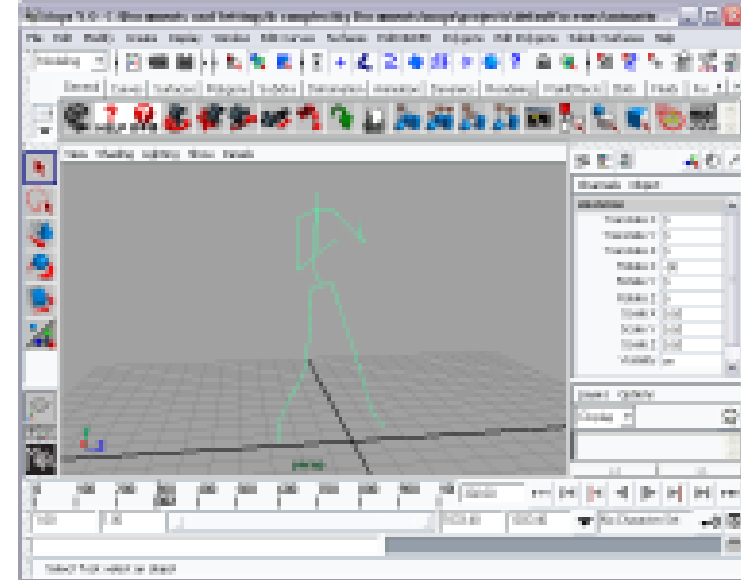




VisoR: Virtual and Interactive Simulation of Reality Research Group 2008

Mocap data

- // Import V-file, then run this
- // Build skeleton
- // Mid-body select -cl; joint -p 0 6 0 -n "pelvis"; joint -p 0 8 1 -n "thorax"; joint -p 0 12 0 -n "head";
- // Left leg select -cl; joint -p 1 6 0 -n "lfemur"; joint -p 1 3 0 -n "ltibia"; joint -p 1 0 0 -n "lfoot"; joint -p 1 0 1 -n "ltoes";
- // Right leg select -cl; joint -p -1 6 0 -n "rfemur"; joint -p -1 3 0 -n "rtibia"; joint -p -1 0 0 -n "rfoot"; joint -p -1 0 1 -n "rtoes";
- // Parent the legs select -cl; parent "lfemur" "pelvis"; parent "rfemur" "pelvis"; // Left arm select -cl; joint -p 0 10 0 -n "lclavicle"; joint -p 1 10 0 -n "lhumerus"; joint -p 3 10 0 -n "lradius"; joint -p 5 10 0 -n "lhand";
- // Right arm select -cl; joint -p 0 10 0 -n "rclavicle"; joint -p -1 10 0 -n "rhumerus"; joint -p -3 10 0 -n "rradius"; joint -p -5 10 0 -n "rhand";
- // Parent the arms select -cl; parent "lclavicle" "thorax"; parent "rclavicle" "thorax";
- // Group skeleton select -r pelvis; group -n "skeleton"; xform -os -piv 0 0 0;
- // Transform skeleton joints to match captured T-pose
- setAttr pelvis.rotateX `getAttr pelvis_local.rotateX`;
- setAttr pelvis.rotateY `getAttr pelvis_local.rotateY`;
- setAttr pelvis.rotateZ `getAttr pelvis_local.rotateZ`;
- setAttr pelvis.translateX `getAttr pelvis_local.translateX`;
- setAttr pelvis.translateY `getAttr pelvis_local.translateY`;
- setAttr pelvis.translateZ `getAttr pelvis_local.translateZ`;



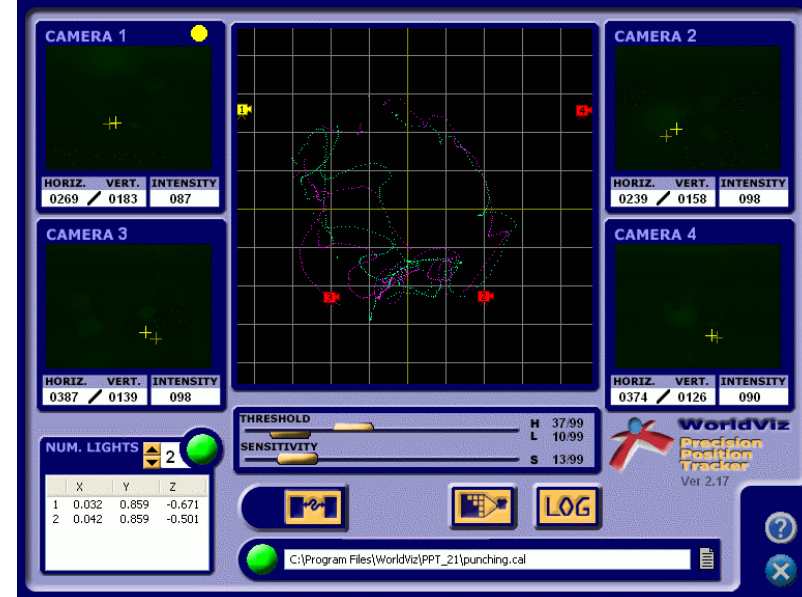
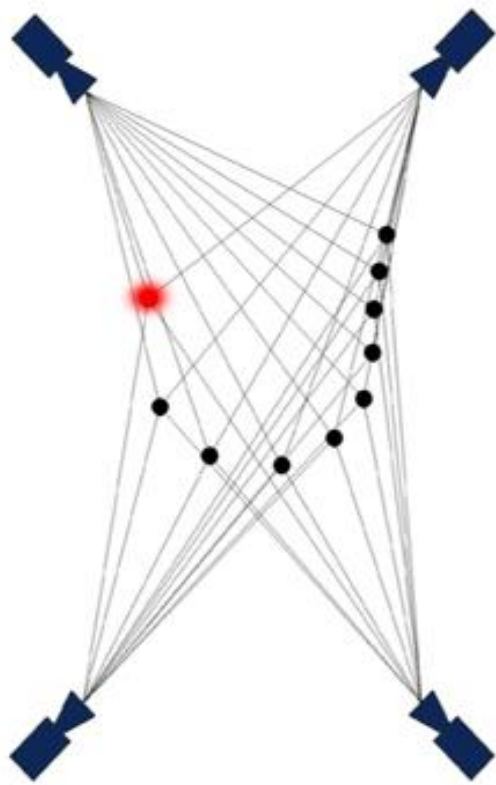
Inertial

- Inertial tracking uses accelerometers
- and gyroscopes. **Accelerometers**
- measure linear acceleration.
 - Since the derivative of position with respect to time is velocity and the derivative of velocity is acceleration, the output of the accelerometer can be integrated to find the velocity and then integrated again to find the position (more precisely, the position relative to some initial point)
- **Gyroscopes** measure angular velocity. The angular velocity can be integrated to determine angular position (more precisely, the angular position relative to the initial point).
- inexpensive, and can provide high update rates and low latency. However, it can lose accuracy over time.
- it is hard to rely on inertial tracking to determine position.
- Works well in combination with other tracking systems.

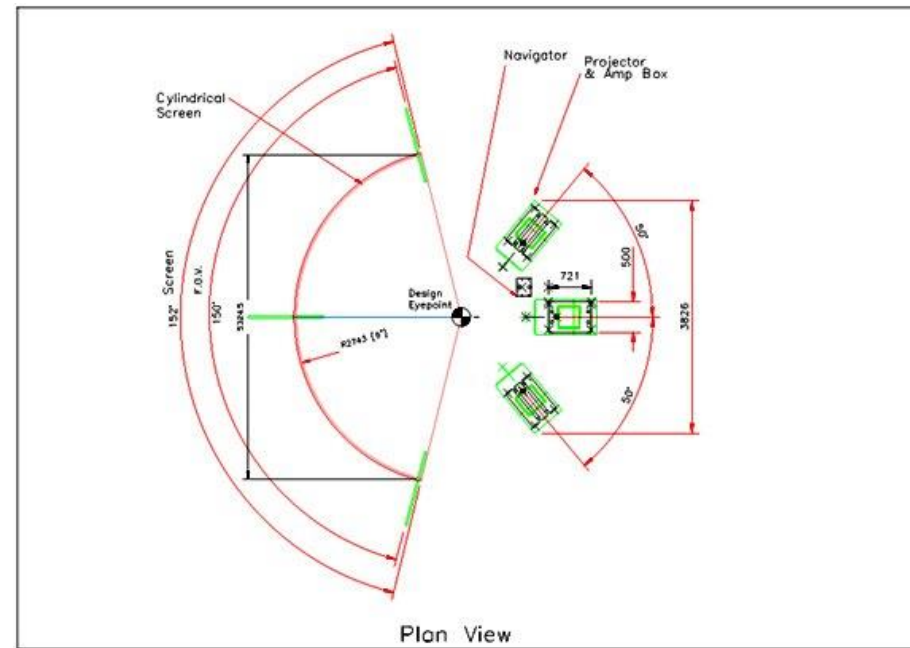


Tracking facial expressions





Optical Motion Tracking The Precision Position Tracker (PPT) system developed by WorldViz uses 4 optical sensors (cameras) to track up to 8 infrared LED markers



VisoR: Virtual and Interactive Simulation of Reality Research Group 2008

Sensor Shirt

- developed by the research teams at the Electronic Engineering Department of University of Pisa, Italy
- consists of piezo-resistive sensor threads smeared on an elastic fabric substrate which allows the user to perform motions without any constraint.



(a)



(b)



(c)

Gesture recognition



Speech & Gesture Recognition



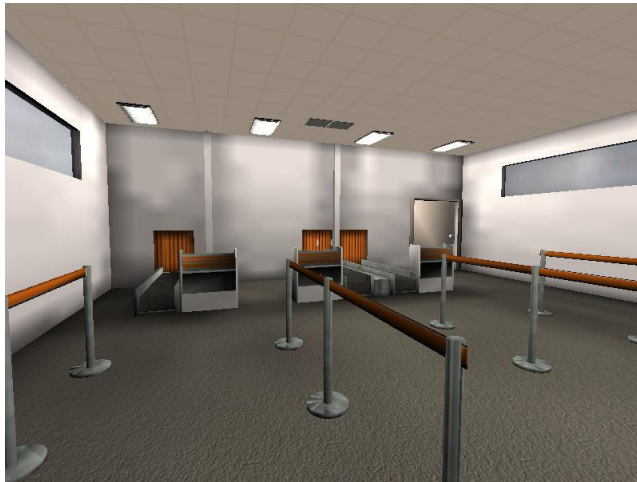
We use Vizard Virtual Reality Software, as well as speech and gesture recognition systems to interact with the characters at an airport.

VisoR: Virtual and Interactive Simulation of Reality Research Group 2008

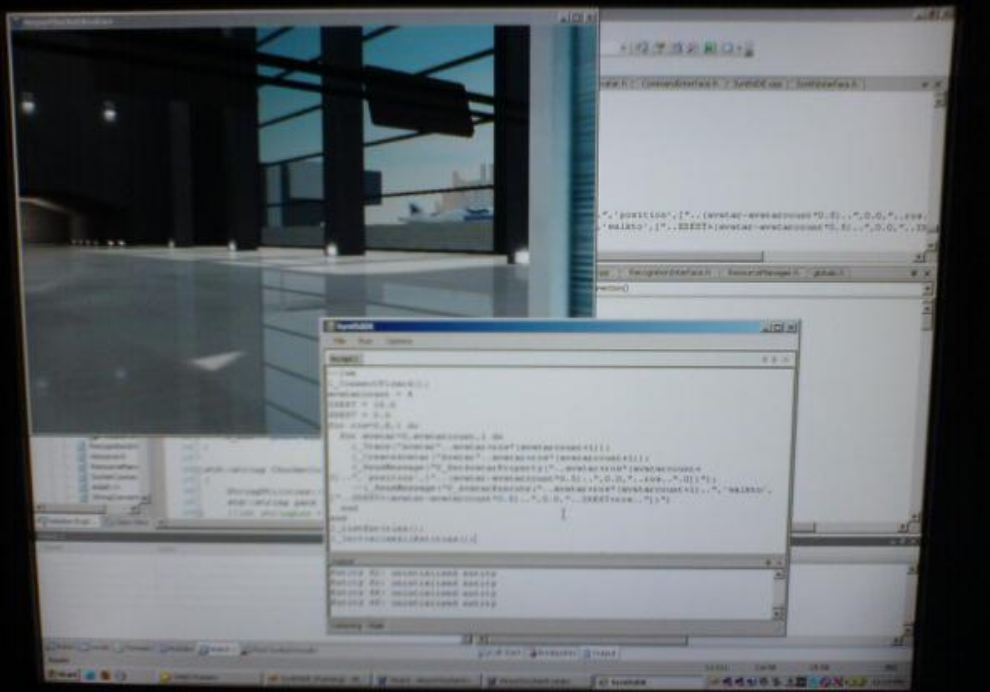
Risk Management Mod

RMM

- the first implementation of our system, in 2005, the Unreal Tournament (UT2004) game engine was used
- to provide the components marked as 3D objects and worlds, scripted agents and voice and sound.



VisoR: Virtual and
Interactive Simulation
of Reality Research
Group 2008



12:19 pm



06-Jul-07 12:25 pm