An Introduction into Virtual Reality Environments

Stefan Seipel
stefan.seipel@hig.se
What is Virtual Reality?

Technically defined:

VR is a medium in terms of a collection of technical hardware (similar to telephone, TV, etc.)
Definitions of Virtual Reality

Coates (1992):
*Virtual Reality is electronic simulations of environments experienced via head mounted eye goggles and wired clothing enabling the end user to interact in realistic three-dimensional situations.*

Greenbaum (1992):
*Virtual Reality is an alternate world filled with computer-generated images that respond to human movements. These simulated environments are usually visited with the aid of an expensive data suit which features stereophonic video goggles and fiber-optic gloves.*

Krueger (1991):
*The term (virtual worlds) typically refers to three-dimensional realities implemented with stereo viewing goggles and reality gloves.*
What is Virtual Reality?

Defined in terms of human experience:

VR is a *mediated* environment which creates the sensation in a user of being present in a (physical) surrounding.
Variables to define Virtual Reality

**Vividness**

(richness of an environments representation)

- breadth (visibility, audibility, touch, smell)
- depth (quality, fidelity)

**Interactivity**

(extend to which a user can modify form and content of a mediated environment)

- speed (update rates, time lag)
- mapping (text, speech, gestures, gaze, complex behavior patterns)
Classification of Virtual Reality and other Media

- Vividness
  - Sensorama
  - 3D IMAX
  - 35mm film

- Interactivity
  - TV
  - pay-TV
  - video conferencing
  - phone
  - tamagotchi

Jonathan Steuer
History of Virtual Reality
(technological milestones)

1956  Sensorama *(Morton Heilig)*
3D visuals, vibration, stereo sound, wind, smell, little interaction

1961  Headsight System *(Philco Corp.)*
HMD, head tracking, remote video camera, telepresence

1965  The Ultimate Display *(Ivan Sutherland)*
Stereoscopic HMD, computer generated images, tracking, visually coupled system

1967  Grope *(University of North Carolina)*
6 degree of freedom force feedback

1977  The Sayre Glove *(Sandin, Sayre, DeFanti Univ. Illinois)*
Gesture recognition

1987  Virtual Cockpit *(British Aerospace)*
head and hand tracking, eye tracking, 3d visuals, 3D audio, speech recognition
vibro tactile feedback
System Architecture in Virtual Environments

- Display Devices
- Sensor Devices
- User
- Render Engine
- Simulation Manager
  - Scene Generator
  - Simulation Loop
- Sensor Handler
- Scene DB
How Do We Perceive 3D?
How Do We Perceive 3D?

Visual depth cues:

a) monoscopic cues
   relative size
   interposition and occlusion
   perspective distortion
   lighting and shadows
   texture gradient
   motion parallax

b) binocular (stereoscopic) cues
   stereodisparity
   convergence
How can we recreate 3D sensation?

Providing visual cues:

a) monoscopic cues
   realistic rendering / lighting simulation

b) stereoscopic cues -> stereodisparity
   presentation of appropriate view to each eye
   - time multiplexing of images
   - multiplexing with chromatic filters (anaglyph)
   - multiplexing with polarizer filters
   - providing two views simultaneously
Color Encoded Stereo Image Pair
Time Multiplexed Stereo Image Pair

Additional V-Sync at 120 Hz (enforced with sync. doubler)

V-Sync at 60 Hz

Active Shutter Glasses (LCD-Shutters)
Dual Channel Head Mounted Display (HMD)  
(© nVision)
What Renders VR Applications Specific?

1. Visual and Acoustic Realism of Objects
   • 3D effect
   • level of detail
   • specularity
   • color and texture

2. Realtime Response (approx. >15 Hz)

3. Natural Like Interaction Metaphors
   (many degrees of freedom input)

4. Peripherial Visual Stimuli
1. Immersive Virtual Environments
   • subjects are visually isolated from the real environment
   • virtual scene is responding to the subjects actions
   • subjects are unable to perform in the real environment

2. Semi-Immersive Virtual Environments
   • subjects can perform both in the real and virtual environment
   • subjects perceive a strong involvement into the VE
   • subjects may perform less in the real environment

3. Non-Immersive Virtual Environments
   • the three-dimensional scene is considered as a part of the physical environment
   • subjects do fully respond in the real environment
   • relatively little involvement into the VE

(4. Augmented Reality Interfaces)
An Immersive Car Simulator Using HMD
(© British Aerospace)
A BOOM Display Application in Aerodynamics
(© NASA Ames Research Center)
CAVE - An Immersive VR Environment
(EVL, University of Illinois at Chicago)
The ImmersaDesk - A Semi- Immersive Device
(University of Illinois at Chicago)
Virtual Reality Command Visualization Environment VR COVE (Vrex Corp.)
The Responsive Workbench
(© GMD, St. Augustin, Germany)
The Haptic Display Grope III
(© University of North Carolina)
The Virtual Workbench
(© 1998 Kent Ridge Digital Labs (KRDL), Singapore)
Non-Immersive Desktop VR : 3D Implant Planning
(© 1995 CMD, Uppsala University)
Steps in Design for VR Environments

Content
• story writing
• scenario setup
• semantics

Objects
• geometry and static attributes (color etc…)
• textures
• sound

Dynamics
• object relationships
• events
• dynamic object properties (behavior)

System Implementation
Display Devices

Visual Displays (3D imagery)
- Head Mounted Displays (HMD)
- Projection Displays (CAVE, Virtual Plane)

Acoustic Displays (spatial sound)
- Multi-Channel Sound Systems
- Specialized Convolution Processors (e.g. Convolvotron)

Haptic Displays (force feedback)
- Robot Arms (e.g. Grope, Phantom)
- Active Joystics (e.g. Microsoft Sidewinder)
- Vibrotactile Devices (e.g. Logitec Cyberman)
Examples of Haptic Devices

PHANToM ©SensibleDevices

High Fidelity Force Feedback Devices

Low Cost Force Feedback Device
Software Tools for Implementation of Virtual Environments

Low Level Tools
- Keep Track of Primitive Lists
- Transformation of Vertices
- Drawing of Primitives
- Reading Devices on Driver Level
- Polygon Intersection Testing

Examples
- C++ Compiler
- OpenGL, Direct3D
Software Tools for Implementation of Virtual Environments

High Level Tools
- Loading Objects (Geometry, Sounds…)
- Scene Graph Construction
- Advanced Camera Models
- Automatic Sensor Handling
- Automatic Collision Detection

Examples
- C++ Compiler
- Simulation Libraries (WorldToolKit, VRT, DIVE, dVise)
- WorldUp, Superscape
Concepts of Simulation Libraries (WorldToolkit, VRTK)

Scene Graph Representation
- Scene is composed of nodes
- Node relationships are expressed in a hierarchical graph
- A node contains geometries, attributes and transformation matrices

Simulation Loop with User Definable Callback Function
- Behaviour is coded in callback function
- Simulation state variables are used for dynamic control
Scene Graph Example

- **root**
  - node1
    - t1
    - node2
    - t2
  - node2
- root
  - node1
    - t1
    - node2
    - t2

© Stefan Seipel 2004
The WorldUp Simulation System
Application Examples from the Uppsala VR Lab

© Stefan Seipel 2004
The Virtual Plane  
(© 1999 CMD, Uppsala University)

Virtual Implant Planning  
Stefan Seipel, 1999

Flight Mission Rehearsal  
Examensarbete Anders Seton, VT99

© Stefan Seipel 2004
The Role of Dynamic Perspective

The alternate-ego view

The primary-ego view
The Role of Dynamic Perspective
The Stereoscopic Powerwall
(© 1999 CMD, Uppsala University)
Automatic Dental Occlusion Analysis
Multi-User Collaborative Shared Virtual Environments

Virtual Teaching Settings for Learning

- low-bandwidth protocols for network VR
- intelligent clients rather than full state replication
- transformation driven state propagation
- highly aggregated objects for net VR
Virtual Teaching in Computer Graphics Education
Virtual Teaching in the Dental Curriculum