Virtual Reality Technology and Programming

TNM053

VR Lectures

4. Human Factors
5. Computer Hardware Rendering
6. VRML and Scene Graphs
7. Projector and Display Technology
8. Haptics
9. Interaction Techniques
10. Interaction Techniques (continued)
11. Applications, Distributed Environments, Future
12. Summary, Revision and Discussion

What is Virtual Reality?

Invented in ~1965

The Ultimate Display

“The ultimate display would, of course, be a room within which the 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 room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.”

Ivan Sutherland, 1965

First attempts (1966)

- Picked up technology from “head-up” helicopter system:
  - Infra-red camera controlled by pilot’s head movements
  - Replace the camera with a computer
  - Instant VR!
Head-mount VR Display

Realities of Virtual Reality
- Never been realized.
- Just imagined:
  - Frequently represented in Science Fiction.

What exists today?
- Virtual Reality
- Virtual Environments
- Augmented Reality
- Immersion (‘Immersive Reality’)

Virtual Reality (VR)
- mainly a visual experience.
- Typically focuses on immersion.
- Often has interaction.
- Not necessarily a realistic environment.

Virtual Environments (VE)
- VR++
- Includes other senses:
  - Sound
  - Touch
  - Smell
  - Motion

Early example of VE
- Stolen from “Kentucky Fried Movie”
Augmented Reality

- Reality viewed in some way which allows additions produced by a computer:
  - Half-silvered displays.
  - Transparent glasses with reflected display.
- Requires extremely accurate tracking.

Immersion

- The first-person view
  - Games
- Highly immersive
- Highly interactive
- Very fast updates
- Very effective, low cost VR trainers have been based on this model

Human Factors

TNM053: VR Technology
Matt Cooper

Material Used

- "Essential Virtual Reality Fast", chapter 4
  - John Vince.
- "The Limits of Human Vision"
  - Michael F. Deering.
- 4 pages from "Measuring Presence in Virtual Environments: A Presence Questionnaire"
  - Bob G. Witmer and Michael J. Singer.
- "Human Factors Issues in Virtual Environments: A Review of the Literature"

Contents

- Human senses and their limitations
- Areas of active research
- Concepts
Human senses
- Vision
- Auditory
- Tactile
- Smell
- Taste
- Vestibular

Areas of research
- Human Performance Efficiency
- Health and Safety
- Social Implications

Concepts
- Presence
- Involvement
- Immersion

Human Performance Efficiency in Virtual Worlds
“...the goal is to build [virtual] environments that minimize the learning required to operate within them but maximize the information yield”
- Wann and Mon-Williams

Factors Contributing to Human Performance Efficiency
- Navigational Complexity
- Degree of Presence
- User performance on benchmark tests:
  - Limitations on trivial activities contribute to problems with higher tasks

Navigational Complexity
- VE design
- Wayfinding
- Dead reckoning
- Homing
- Spatial Orientation
- Time to Collision
- Geographical Orientation
- Vestibular Functions
Vestibular functions

Degree of Presence

- Vividness
- Interaction
- Involvement
- Immersion

Metaphors

- Humans learn a ‘grammar’ or language about virtual experiences
  - Rules about the way things are done
  - Rules about what they mean
- The exploitation can be very subtle and very powerful

Users’ performance on benchmark tasks

- Ability to:
  - Move through the virtual world
  - Manipulate and track virtual objects
  - Locate virtual sounds
  - Respond to kinesthetic force-feedback
  - Perform visual tasks:
    - Perceive and discriminate colours
    - Judge virtual distance...
    - Search for...
    - Recognize and...
    - Estimate the size of virtual objects

To justify using VE technology for a given task

- Use of VE should improve task performance when transferred to the real-world task.
- What type of tasks?
- Relationship of real task characteristics and VE characteristics is important:
  - Stereoscopic 3D visualization
  - Real-time interactivity
  - Immersion

User Characteristics

- Physical (e.g. interpupil distance)
- Perceptual and Cognitive Style
  - Expert vs. Novice
  - Orientation
  - Spatial Memory
- Personality
- Age
Human Sensory limitations

- Visual perception
- Auditory perception
- Physiology of haptic and kinesthetic perception

Visual Perception

- Field of view (FOV)
- Acuity
- Stereopsis:
  - Depth Cues
  - Binocular Rivalry/Eye dominance

Visual field

- Horizontally:
  - -9° to +110°
  - 118° overlap where stereopsis occurs
- Vertically:
  - -70° to +56°
- Highest resolution perceivable pixel: 28° of arc
- Variable resolution:
  - Light to Dark Adaptation: 25000:1
- Limits of rendering:
  - 60 frames/second
  - 2 eyes
  - 14.83M pixels
  - 6 DC
  - 10.68 B

Field of View examples

<table>
<thead>
<tr>
<th>Display device</th>
<th>Pixel Resolution</th>
<th>Pixel Size (mm. of arc)</th>
<th>Display FOV (steradians)</th>
</tr>
</thead>
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<tr>
<td>18” CRT at 60cm</td>
<td>1280 x 1024</td>
<td>1.6</td>
<td>0.25</td>
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<tr>
<td>31” TV at 3.5M</td>
<td>640 x 480</td>
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<td>50” film at 20M</td>
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<td>137” IMAX at 23M</td>
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<td>1.07</td>
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<td>10” workbench at 1m</td>
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<td>9.5</td>
<td>2.55</td>
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<tr>
<td>95” HMD</td>
<td>1280 x 1024</td>
<td>4.0</td>
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<td>3 wall virtual portal</td>
<td>3 x 1024 x 1280</td>
<td>6.7</td>
<td>6.73</td>
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<tr>
<td>Human eye</td>
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<td>-</td>
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<tr>
<td>Full Sphere</td>
<td>-</td>
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</tbody>
</table>

Depth Cues

- Binocular disparity (stereo glasses)
- Occlusion
- Perspective projection
- Motion parallax
- Convergence (amount eyes rotate inwards)
- Focus (of a single eye)
- Atmospheric (fog)
- Lighting and shadows
- Experience!

Auditory perception

- 3D audio localization
  - Intensity (= 35 dB)
  - Temporal difference (= 700μS)
  - Phase difference
  - Anatomy of external ear, Pinna
    - Head-Related Transfer Function (HRTF)
Physiology of Haptic and Kinesthetic Perception

- A haptic sensation (e.g. touch) is a mechanical contact with the skin.
- Mechanical stimuli produce a sensation of touch:
  - Displacement of skin over an extended period
  - Transitory (milliseconds) displacement of skin
  - Transitory displacement repeated at constant or variable frequency
- Difficult to characterize in quantitative way
- Sensations of skin adapt with exposure to stimuli

Receptor types

- Phasic receptors
  - Rapidly adapt and relate to pressure and touch
- Tonic receptors
  - Related to pain and body position, slowly adapt and may have an afterimage that persists even once the stimuli are removed.
- Kinesthesia
  - Awareness of the movements and relative position of body parts
  - Proprioceptive sensors

Multimodal interaction

- Enhance human performance
- Sensorial redundancy
- Redundant “input”
  - Is that necessary/possible
- Health issue

VE design metaphors

- VR sliders (comp. 2-D scrollbars)
- 3-D map cubes
- Portals
- Spirals
- ...

VE designers have almost endless design possibilities and (but ?) limited guidance in designing efficient HVEI.

Health and Safety issues

- Flicker
- Electro-Magnetic Fields
- X-rays
- Laser Light
- Direct macroscopic effects
  - Eyestrain
  - Esophoria (inward turning of the eyes)
  - Phobic effects
  - Walkman effect
Other macroscopic effects

- Movement injuries from heavy equipment
- Bumps and bruises:
  - Haptic feedback devices
  - Surprising sounds
- ‘Cybersickness’

Cybersickness

- A reverse form of ‘motion sickness’
- Caused by:
  - ‘Vection’ – Illusion of self-motion in a VE
  - Lag – Delay in (visual) feedback
    - Particularly bad in HMD’s
  - FOV – Both wide and narrow FOV. Often drives vection
  - Level of interactive control

Indirect effects

- After-effects:
  - Head spinning
  - Reduced eye-hand coordination
  - Vestibular disturbances
  - Nausea
- The human nervous system adapts

Social effects

- ?

Summary

- Technology is very new:
  - No well defined rules
  - Displays and interactors are still primitive
- Methods have a lot to offer:
  - Familiarity of environment
  - Ability to convey much information
- Keep human factors in mind:
  - Drive the system from human abilities