Virtual Reality Technology and Programming

4a - What is Virtual Reality?

Matt Cooper

VR

- 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 a 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.

Augmented Reality

- Work from UNC Chapel Hill
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

4b 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

A metaphor

- From Notting Hill

Puncturing the illusion

- We know things about the world
- We know things about the grammar
- Break those rules at your peril

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. interpupillary 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:
  - -59° to +110°
  - 11° 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 · 1 pixel = 10.68 B /s

Field of View examples

<table>
<thead>
<tr>
<th>Display device</th>
<th>Pixel Resolution</th>
<th>Pixel Size (min. of arc)</th>
<th>Display FOV (steradians)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18&quot; CRT at 60cm</td>
<td>1280 x 1024</td>
<td>1.6</td>
<td>0.25</td>
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<tr>
<td>31&quot; TV at 3.5m</td>
<td>640 x 480</td>
<td>1.0</td>
<td>0.03</td>
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<tr>
<td>50&quot; film at 20M</td>
<td>2350 x 1000</td>
<td>1.0</td>
<td>0.19</td>
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<tr>
<td>137&quot; IMAX at 23M</td>
<td>4096 x 3002</td>
<td>1.2</td>
<td>1.07</td>
</tr>
<tr>
<td>10&quot; workbench at 1m</td>
<td>1280 x 1024</td>
<td>9.5</td>
<td>2.55</td>
</tr>
<tr>
<td>95&quot; HMD</td>
<td>1280 x 1024</td>
<td>4.0</td>
<td>1.23</td>
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<tr>
<td>3 wall virtual portal</td>
<td>1024 x 1280</td>
<td>6.7</td>
<td>6.73</td>
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<tr>
<td>Human eye</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Full Sphere</td>
<td>-</td>
<td>-</td>
<td>12.57</td>
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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

Smell and taste

- Very new area of research
- Taste is very limited
  - Four components:
    - Salt
    - Sweet
    - Acid
    - Sour
- Most of ‘taste’ is actually smell

Smell

- Attempts have been made to synthesize scents on demand
  - Scent box with a set of chemicals
  - Combinations (under computer control)
  - Blown at the user
- Becoming more elaborate all the time.

Virtual food

University of Tsukuba
### 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
  - Eye strain
  - 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
<table>
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<tr>
<th>Social effects</th>
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<table>
<thead>
<tr>
<th>Summary</th>
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<tbody>
<tr>
<td>Technology is very new:</td>
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<tr>
<td>- No well defined rules</td>
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<tr>
<td>- Displays and interactors are still primitive</td>
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<tr>
<td>Methods have a lot to offer:</td>
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<tr>
<td>- Familiarity of environment</td>
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<td>- Ability to convey much information</td>
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<tr>
<td>Keep human factors in mind:</td>
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<tr>
<td>- Drive the system from human abilities</td>
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