Virtual Reality

"computer-simulated environments that can simulate physical presence in places in the real world, as well as in imaginary worlds"

Virtual reality

- One of the “hottest” R&D areas today
- Applications
  - medical training, future surgery?
  - interior design, civil engineering
  - videoconferencing
  - exploration of future worlds
  - ethics, philosophy, psychology, who am I, and what are we?

Virtual reality is a “hot” topic today

- Many startup companies
- Games
- Film
- Design (create 3D models, animations in VR)
- Social networks

History of virtual reality

- 50+ years of history

14 grand challenges in engineering (by the US National Academy of Engineering)

- Make Solar Energy Economical
- Provide Energy from Fusion
- Develop Carbon Sequestration Methods
- Manage the Nitrogen Cycle
- Provide Access to Clean Water
- Restore and Improve Urban Infrastructure
- Advance Health Informatics
- Engineer Better Medicines
- Reverse-Engineer the Brain
- Prevent Nuclear Terror
- Secure Cyberspace
- Enhance Virtual Reality
- Advance Personalized Learning
- Engineer the Tools of Scientific Discovery
Cinerama

- Expand movie-going experience by filling a larger portion of the audience's visual field
- Required special cameras to film
- Proved too costly to be embraced by most commercial theaters


1950s

Cinerama

How the west was won, 1962 (John Ford)

Virtual reality and film

- VR heavily influenced by film techniques
- Hollywood, from early 1950s

1982

2009

Avatar (2009)

Immersion

- The feeling of "being there"
- User becomes part of the simulated world
- Rather than the simulated world being a feature in the user's world

The virtual reality triangle

Real-time

Immersion

Interaction

1982

2009
**Interaction**

- Possibility of moving in the virtual space and manipulate objects
- Without it, illusion breaks down quickly

**Real-time**

- Actions should immediately affect the world
- Computers must simulate the world
- Huge computational burden
- Large computer science challenges

**Head-mounted displays**

- Requires rapid update rates (min 30 fps, preferably 60 fps)
- Very fast tracking and redisplay
- Short lag times
- No noticeable delay between movement and production of correct visuals
- If these are not satisfied \(\Rightarrow\) simulator sickness

**Requirements for virtual reality**

- 3D stereoscopic display
- Wide field of view display (e.g., 100-110 degrees)
- Low latency head tracking (Oculus: 30 msec)
Tracking

- Head: gyroscope, accelerometer, LED lights + external camera
- Hands, body: invisible infrared laser, external cameras
- “Outside-in” vs “Inside-out”
- Eye tracking: using infra-red sensors
  1. correct depth of field
  2. know where the user is looking

Cave

- Project 3D CG into a cube with displays surrounding the viewer
- Coupled with head tracking systems (and other tracking systems e.g. hand)
- Usually surround audio feedback
- Viewer explores virtual world by moving and interacting in the virtual environment

Augmented reality

- Enhances your reality with graphics, haptics, sound

Augmented reality headsets

- Microsoft HoloLens (Microsoft); released HoloLens 2 in Feb 2019
- Magic Leap One (Aug 2018) (Magic Leap)

The different realities

Virtual Reality vs Augmented Reality

<table>
<thead>
<tr>
<th></th>
<th>Virtual Reality</th>
<th>Augmented Reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling complexity</td>
<td>Requires high-resolution models</td>
<td>Not so demanding as VR</td>
</tr>
<tr>
<td>Display technology</td>
<td>Wide field of view</td>
<td>Can be narrow field of view</td>
</tr>
<tr>
<td>Tracking</td>
<td>Not as demanding as AR</td>
<td>Must be high-quality</td>
</tr>
</tbody>
</table>
Virtual reality “hardware”

Flight simulators
- Key driving force of virtual reality technologies
- US Air Force, NASA
- Friend/foe identification
- Targeting/threat information
- Optimal flight path

Flight simulators
- Must manage and render the virtual world
- Shadows and textures
- Motion and force feedback
- Professional flight simulators are still very expensive (millions of $)

Train simulation
Fujitsu train simulator (2008)

Tank simulator
Stryker armored vehicle simulator

Application in medicine: Phobia treatment
Source: Dave Pape (VPL Research, Jaron Lanier)
Source: VirtuSphere
Source: Mario Tama, Getty Images
Source: NASA
Source: Thales flight simulator
Source: Jason Kayes, U.S. Army
Source: Virtually Better, Inc.
Application in medicine: Phobia treatment

Source: Virtually Better, Inc.

Application in TV and sports

First-down line
Source: SporTVision

Haptic interfaces

• hap·tic ('hap-tik) adj.
  Of or relating to the sense of touch; tactile.

Source: SporTVision

Force-feedback rendering

Phantom 3-DoF device (Sensable)

Force-feedback rendering

Xu and Barbic 2016

Simulation in games

Xu and Barbic 2016

Simulation in games

Silent Hunter 4 (Ubisoft)
Virtual reality in games

Source: Colin Anderson

Discussion

• Can we simulate anything?
• What is reality?

Why virtual worlds?

Leontopodium alpinum
Source: appolonio&battista