Virtual and Augmented Reality
Part 1/2 – virtual reality

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The slides used in this lecture are the courtesy of Gordon Wetzstein. From Virtual Reality course: http://stanford.edu/class/ee267/
the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors.
simulation & training
gaming
education
visualization & entertainment
robotic surgery
virtual travel
remote control of vehicles, e.g. drones
architecture walkthroughs
a trip down the rabbit hole
Vision treatment in VR

- Treatment of amblyopia
  - Training the brain to use the “lazy” eye

Images courtesy of VIVID Vision
Exciting Engineering Aspects of VR/AR

- cloud computing
- shared experiences
- compression, streaming
- VR cameras
- photonics / waveguides
- human perception
- displays: visual, auditory, vestibular, haptic, ...
- sensors & imaging
- computer vision
- scene understanding
- CPU, GPU
- IPU, DPU?
- HCI
- applications

Images by Microsoft, Facebook
Where We Want It To Be
Personal Computer
e.g. Commodore PET 1983

Laptop
e.g. Apple MacBook

Smartphone
e.g. Google Pixel

AR/VR
e.g. Microsoft Hololens
A Brief History of Virtual Reality

Stereoscopes
Wheatstone, Brewster, ...

VR & AR
Ivan Sutherland

Nintendo
Virtual Boy

VR explosion
Oculus, Sony, HTC, MS, ...

1838
1968
1995
2012-2018

???
Ivan Sutherland’s HMD

• optical see-through AR, including:
  • displays (2x 1” CRTs)
  • rendering
  • head tracking
  • interaction
  • model generation

• computer graphics
• human-computer interaction

I. Sutherland “A head-mounted three-dimensional display”, Fall Joint Computer Conference 1968
Nintendo Virtual Boy

- computer graphics & GPUs were not ready yet!

Game: Red Alarm
Where we are now
Virtual Image

\[ \frac{1}{d} + \frac{1}{d'} = \frac{1}{f} \]

Problems:

- fixed focal plane
- no focus cues 😞
- cannot drive accommodation with rendering!
- limited resolution
A dual-resolution display

- High resolution image in the centre, low resolution fills wide field-of-view
- Two displays combined using a beam-splitter

Image from: https://varjo.com/bionic-display/
Advanced Graphics & Image Processing

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Pepper’s Ghost 1862
Google Glass
Meta 2

- Larger field of view (90 deg) than Glass
- Also larger device form factor
Microsoft HoloLens
diffraction grating

small FOV (30x17), but good image quality
Microsoft HoloLens 2

- Wider field of view (52 deg)
- High resolution (47 pix per deg)
- Improved ergonomics
- Better hand tracking
Zeiss Smart Optics

- great device form factor
- polycarbonate light guide – easy to manufacture and robust
- smaller field of view (17 deg)
Sony IMX-001

- also great form factor
- small FOV (9x6 deg)
- monochrome
Video AR: ARCore, ARKit, ARToolKit, ...
VR/AR challenges

- Latency (next lecture)
- Tracking
- 3D Image quality and resolution
- Reproduction of depth cues (last lecture)
- Rendering & bandwidth
- Simulation/cyber sickness
- Content creation
  - Game engines
  - Image-Based-Rendering
Simulation sickness

- Conflict between vestibular and visual systems
  - When camera motion inconsistent with head motion
  - Frame of reference (e.g. cockpit) helps
  - Worse with larger FOV
  - Worse with high luminance and flicker
References

  - http://vr.cs.uiuc.edu/
- Virtual Reality course from the Stanford Computational Imaging group
  - http://stanford.edu/class/ee267/