Advanced Graphics & Image Processing

Virtual and Augmented Reality

Part 1/2 – virtual reality

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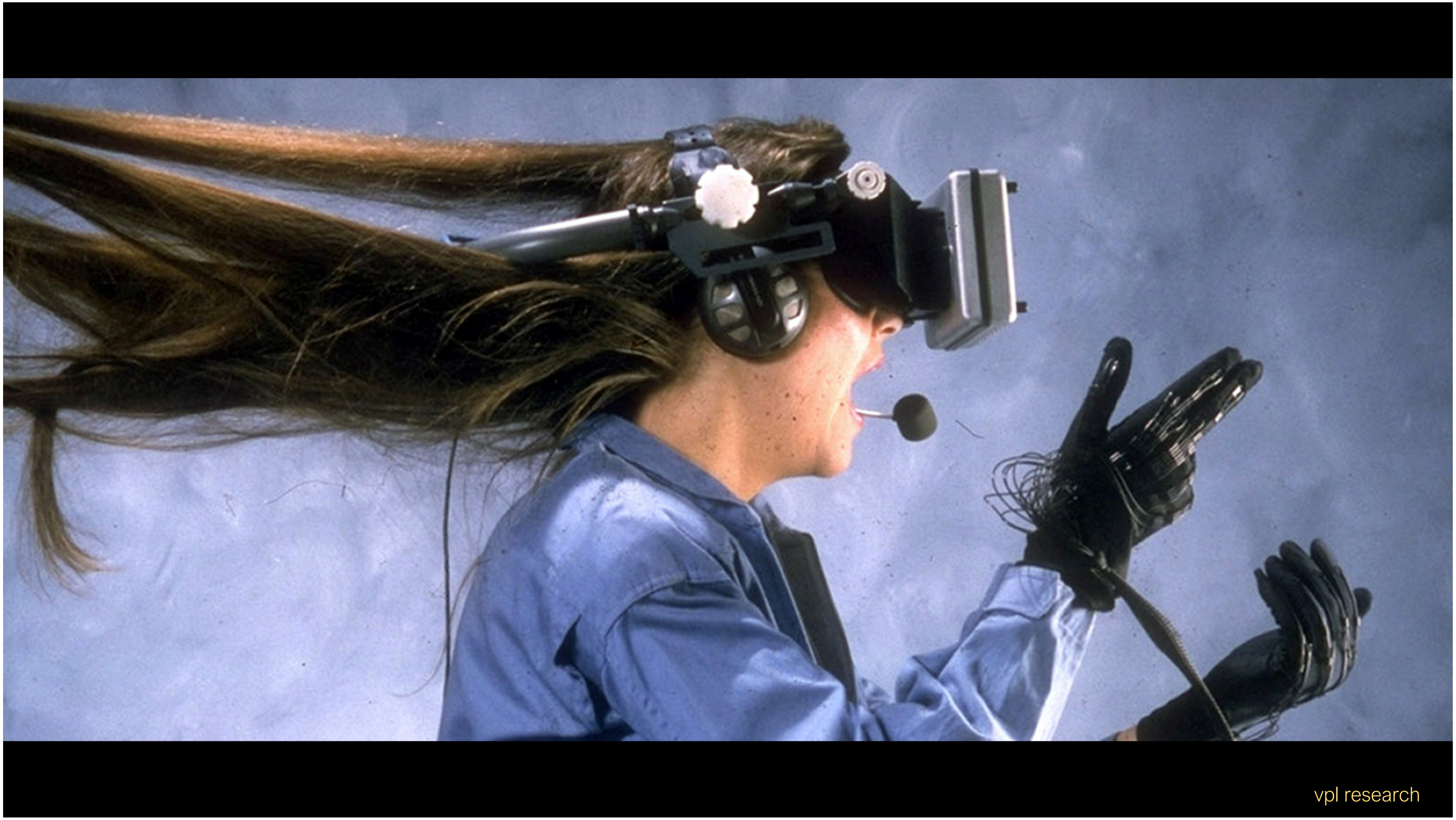
The slides used in this lecture are the courtesy of Gordon Wetzstein.
From Virtual Reality course: http://stanford.edu/class/ee267/


vpl research

simulation & training

visualization & entertainment

remote control of vehicles, e.g. drones

gaming

robotic surgery

architecture walkthroughs

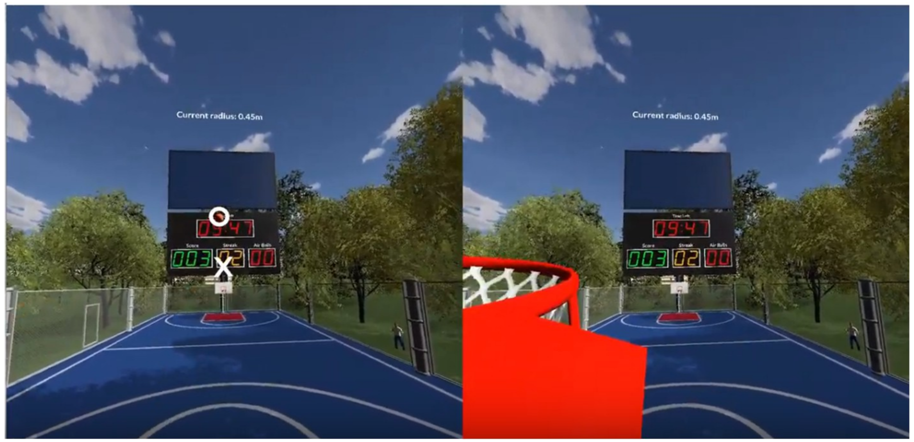
education

virtual travel

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

- CPU, GPU
- IPU, DPU?

- compression, streaming

- sensors & imaging
- computer vision
- scene understanding

images by microsoft, facebook

- VR cameras

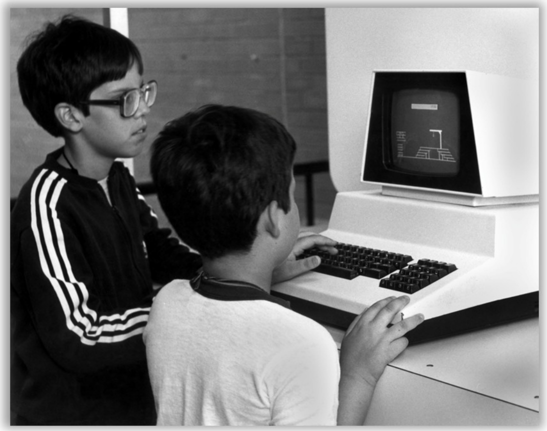
- photonics / waveguides
- human perception
- displays: visual, auditory, vestibular, haptic, …

- HCI
- applications

Where We Want It To Be

image by ray ban

Personal Computer
e.g. Commodore PET 1983



Laptop
e.g. Apple MacBook

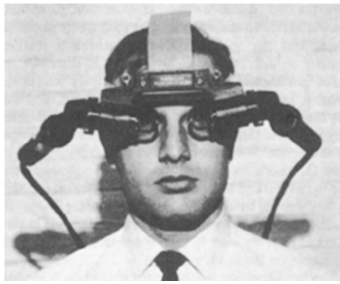
Smartphone
e.g. Google Pixel

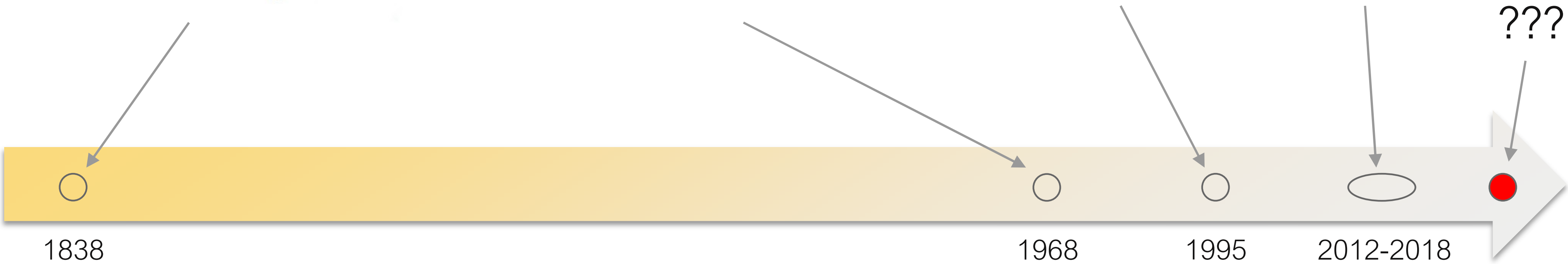
AR/VR
e.g. Microsoft Hololens

???

A Brief History of Virtual Reality

Stereoscopes	VR & AR	Nintendo Virtual Boy	VR explosion
Wheatstone, Brewster, …	Ivan Sutherland		Oculus, Sony, HTC, MS, …

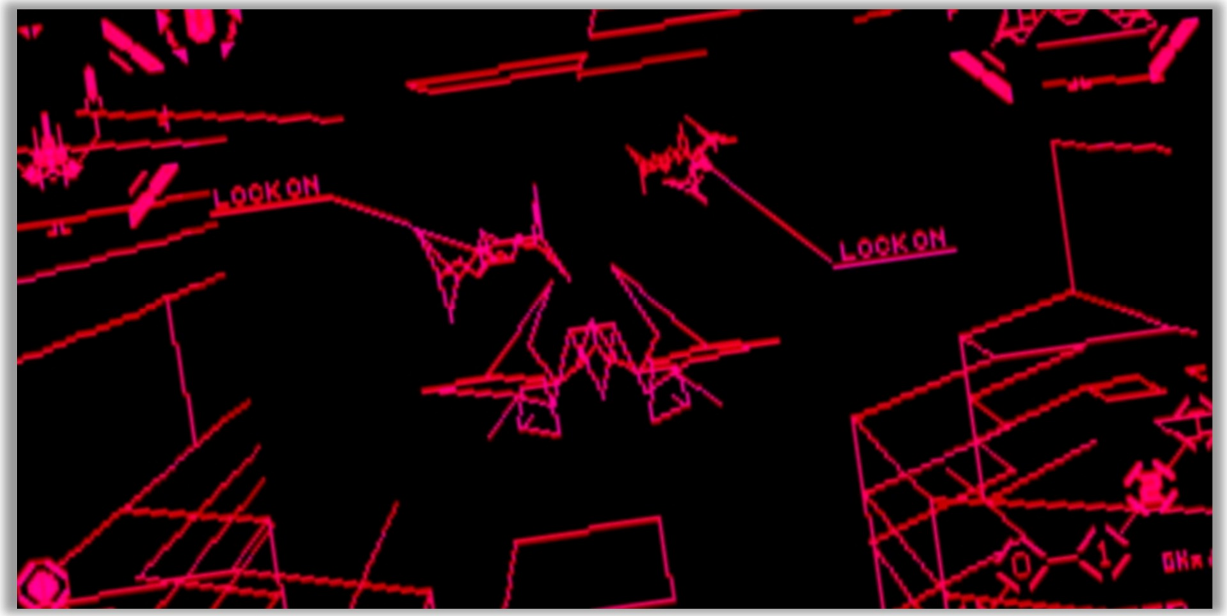
Ivan Sutherland's HMD

- 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!

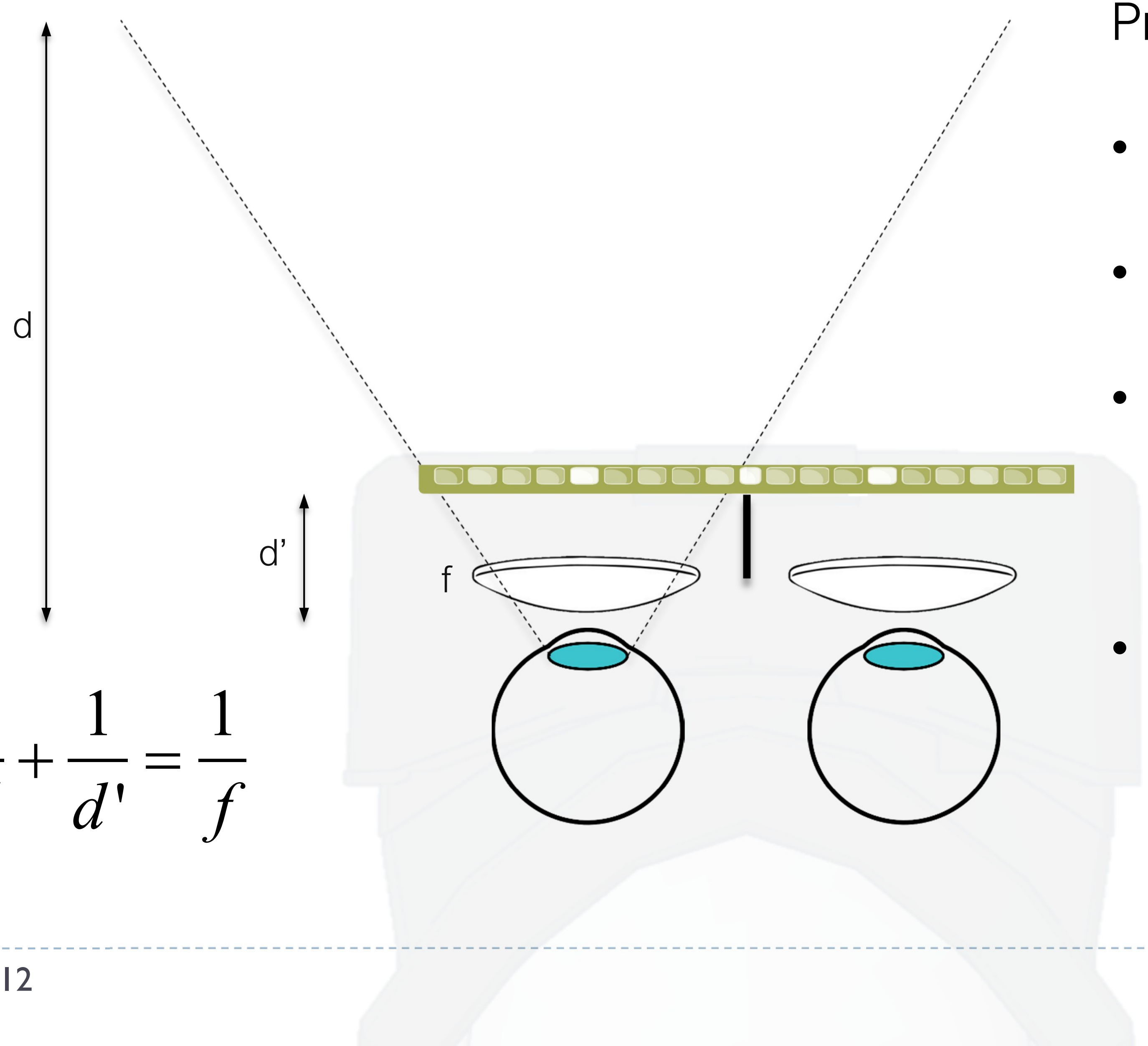


Game: Red Alarm

Where we are now

IFIXIT teardown

Virtual Image

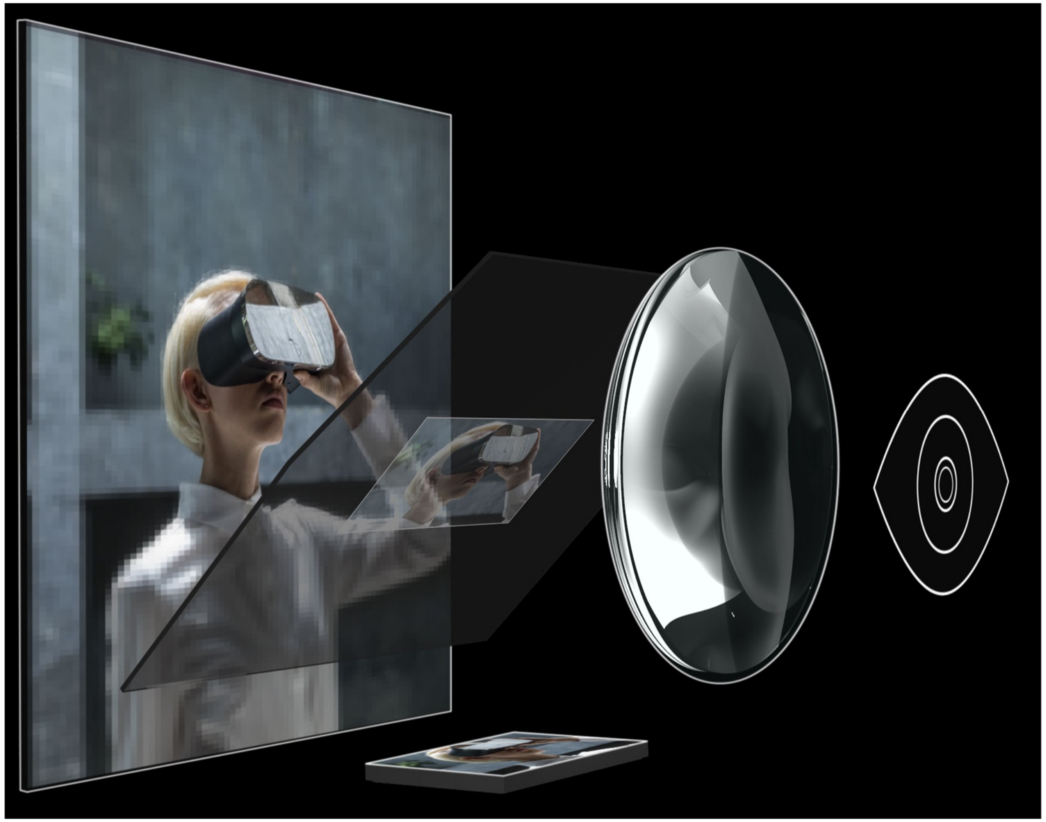


$$\frac{1}{d} + \frac{1}{d'} = \frac{1}{f}$$

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/

UNIVERSITY OF CAMBRIDGE COMPUTER LABORATORY

RAINBOW GRAPHICS GROUP

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Pepper's Ghost 1862

Optical see-through AR / head-up displays

Magic Leap 2

Microsoft Hololens 2

Lumus Maximums

Meta 2
(not the current Meta/Facebook)

Intel Vaunt

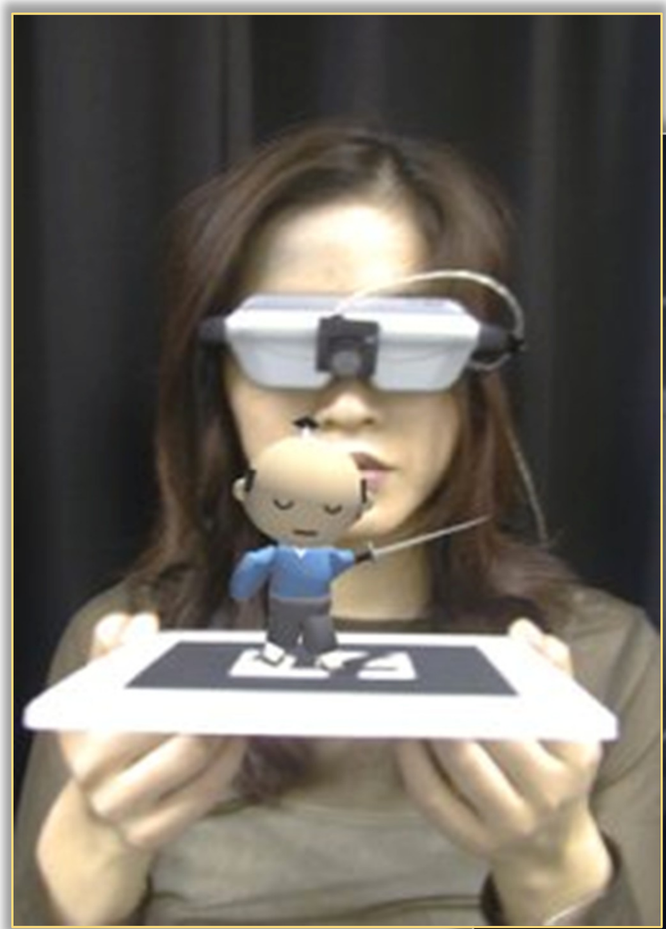
Google Glass

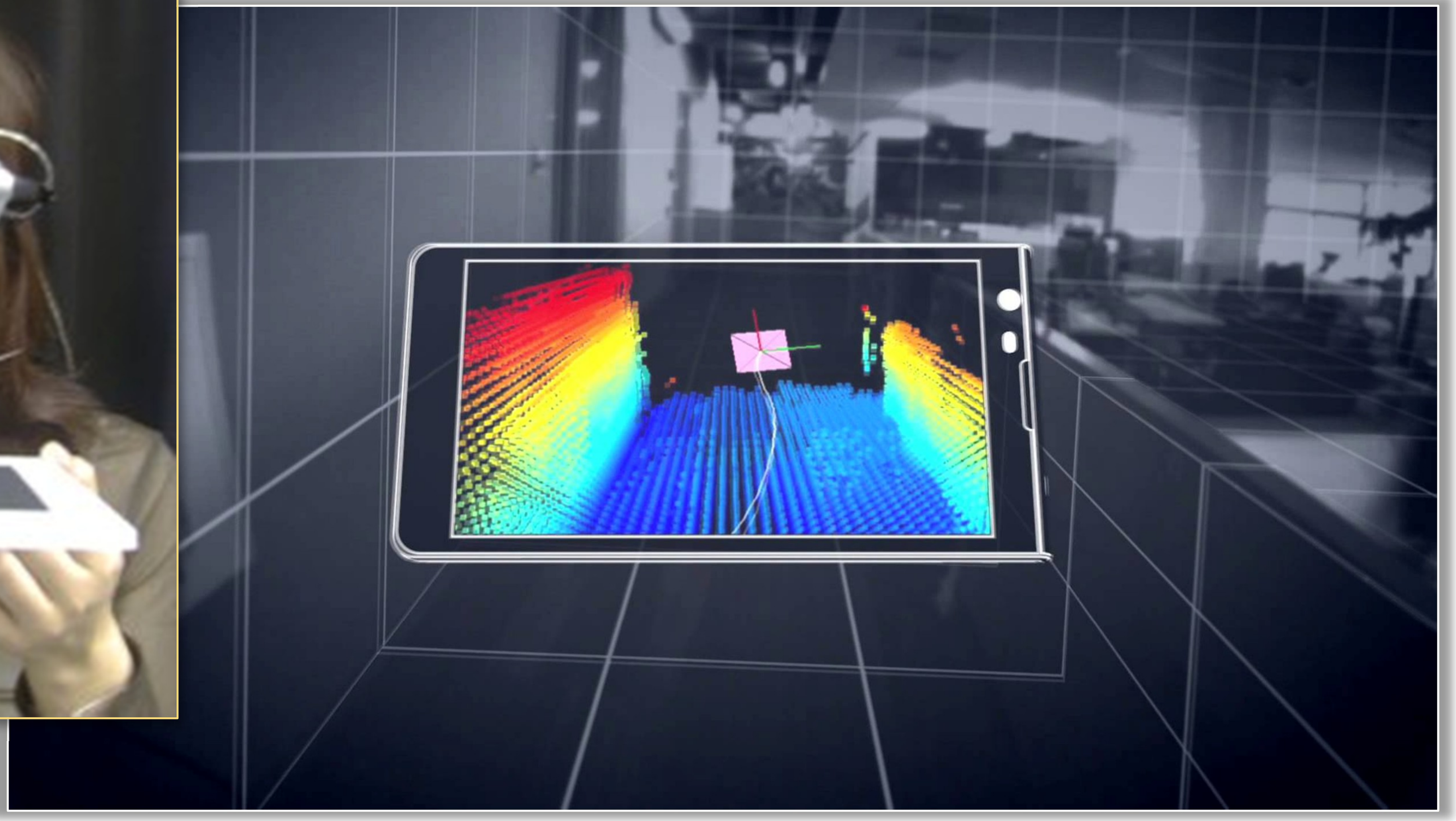
(Some) challenges of optical see-through AR

- Transparency, lack of opacity
  - Display light is mixed with environment light
- Resolution and field-of-view
- Eye-box
  - The volume in which the pupil needs to see the image
- Brightness and contrast
- Blocked vision – forward and periphery (safety)
- Power efficiency
- Size, weight and weight distribution
  - 50 grams are comfortable for long periods
- Social issues, price, vision correction, individual variability…

More resources: https://kguttag.com/

Video pass-through AR: ARCore, ARKit, ARToolKit, …





Video pass-through AR

Pros:

- Better virtual image quality
- Occlusions are easy
- Simpler, less expensive optics
- Virtual image not affected by ambient light
- AR/VR in one device

Cons:

- Vergence-accommodation conflict (see next lecture)
- Lower brightness, dynamic range and resolution than real-world
- Motion to photon delay
- Real-world images must be warped for the eye position (artifacts)
- Peripheral vision is occluded
  - Or display if affected by ambient light

Meta Project Cambria (Quest Pro)

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

- LaValle "Virtual Reality", Cambridge University Press, 2016
  - http://vr.cs.uiuc.edu/
- Virtual Reality course from the Stanford Computational Imaging group
  - http://stanford.edu/class/ee267/
- KGOnTech blog
  - https://kguttag.com/