Challenges in Wireless XR

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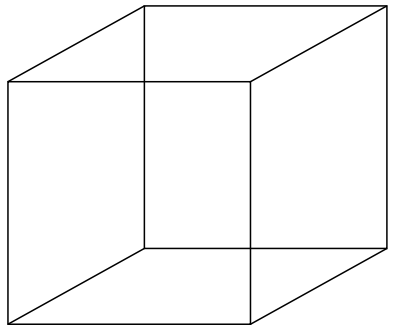
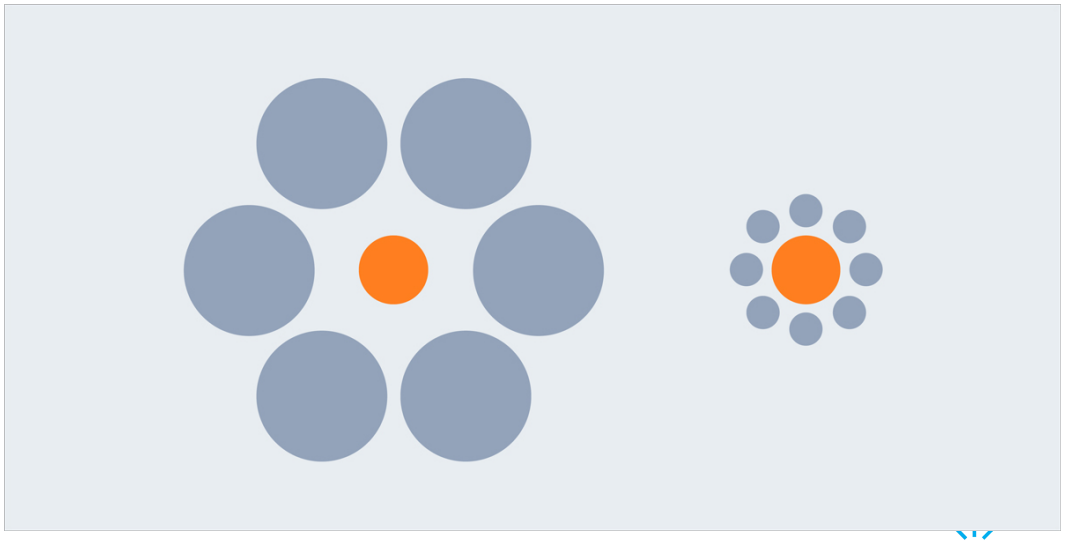
What Is This Technology?

Engineering perceptual illusions

Wearing a display



Optical/audio illusions

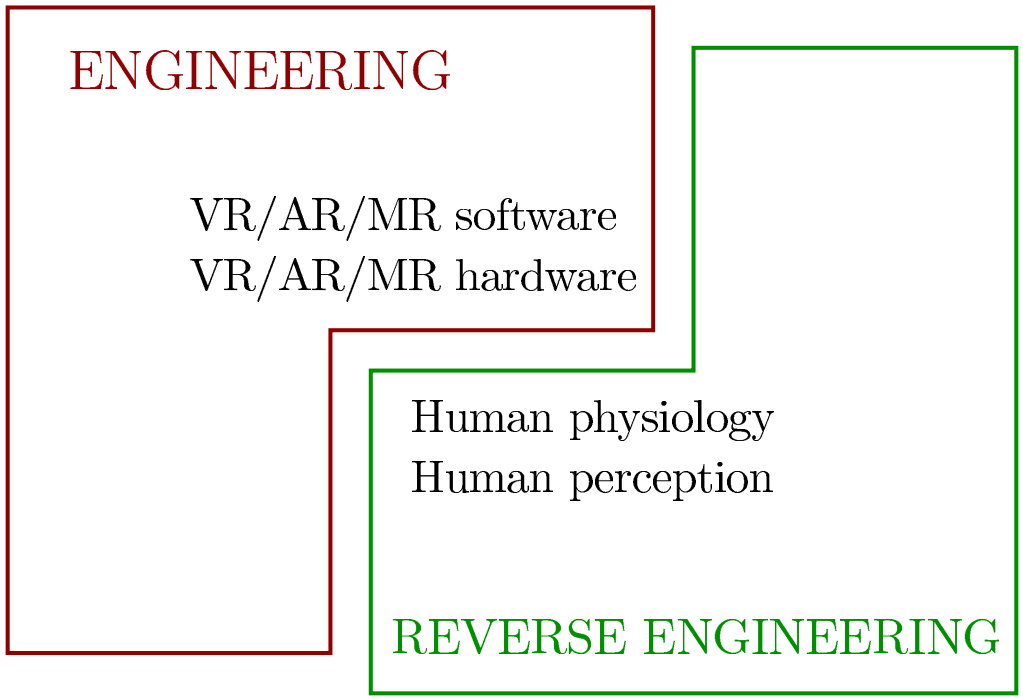


Perception Engineering: An Emerging Discipline

From science to engineering:

- Physics $\rightarrow$ civil, mechanical, electrical engineering
- Chemistry $\rightarrow$ chemical engineering
- Biology $\rightarrow$ bioengineering

Perception science and neuroscience $\rightarrow$ Perception engineering



Related to HRI, HCI, BMI

Consumer XR Devices

Oculus/FB Rift

Sony Morpheus

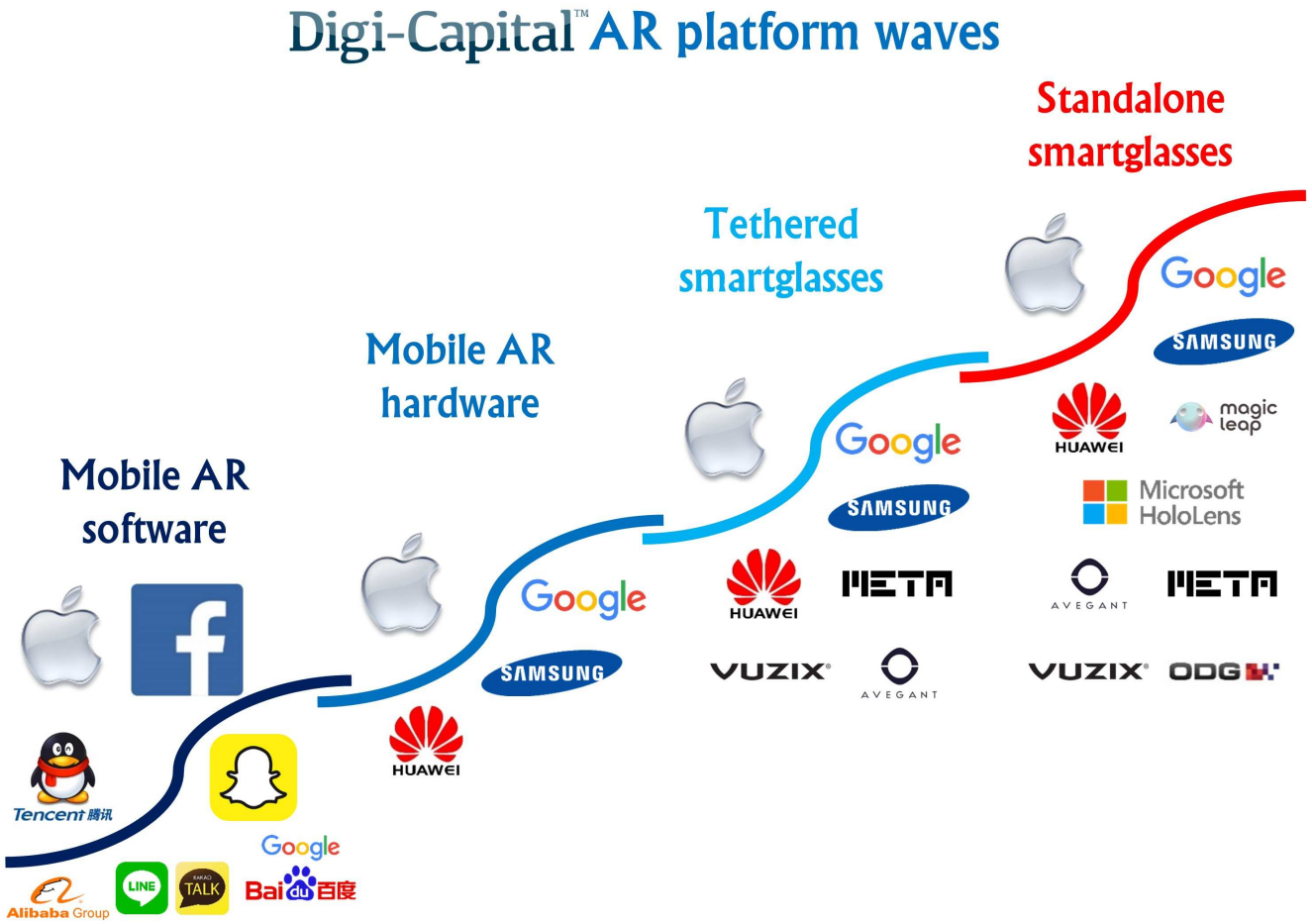
Microsoft Hololens

Google Daydream

Samsung Gear VR

HTC Vive

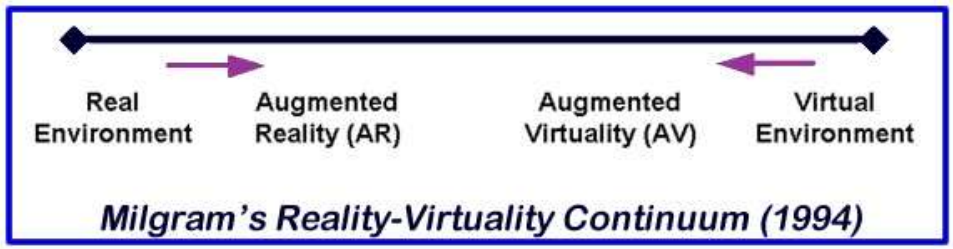
Four Waves of AR



Classical Terms

- Virtual Reality: Immanuel Kant (1796), Jaron Lanier (1980s)
- Augmented Reality: Tom Caudell (1990)
- Mixed Reality: Paul Milgram and Fumio Kishino (1994)

Milgram's spectrum

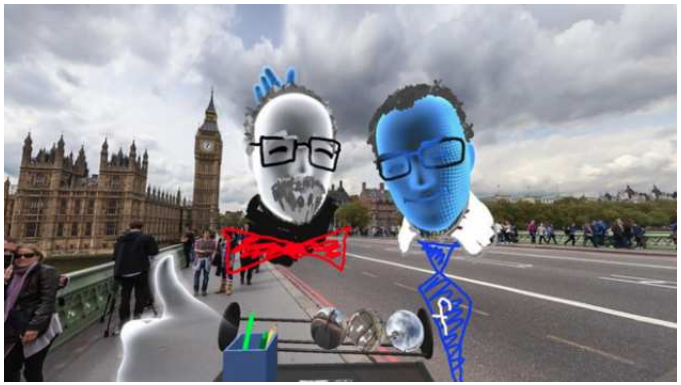


AR/MR (Cast AR)

VR (Oculus)

Old Terms, Confusing New World

Old VR/AR/MR boundaries are increasingly pointless...



Facebook/Oculus VR

Microsoft AR/MR

- Consumer technology has rapidly advanced since 1990s.
- VR device simulates AR device and vice-versa.
- Image, panorama capture, streaming, embedding blurs boundaries.

Shifting Terminology

VR + AR + MR + ... = **XR**

New display and interaction technologies will unify them all anyway...

What Will be the Killer App?

The Economist | World politics | Business & finance | Economics | Science & technology | Culture | Blogs

VR and the future of computing

Awaiting its iPhone moment

Virtual reality is a promising technology, but will not go mainstream in its current form

Aug 29th 2015 | From the print edition | Timekeeper | Like 788 | Tweet 200

IS IT vividly realistic—or is it still just vapid razzmatazz? Virtual reality (VR), a technology that flopped in the 1990s, is making a glitzy comeback. The dream of a headset that can

Comn
E-mai
Print
Follo
Latest

Compare to the smartphone industry from 2000 to 2015.

General Industry Problem: Recycling

Everyone has been leveraging components and experiences that already exist:

- Hardware: Smartphone screens, MEMS sensors, GPUs
- Software: Game engines, graphics techniques for screens

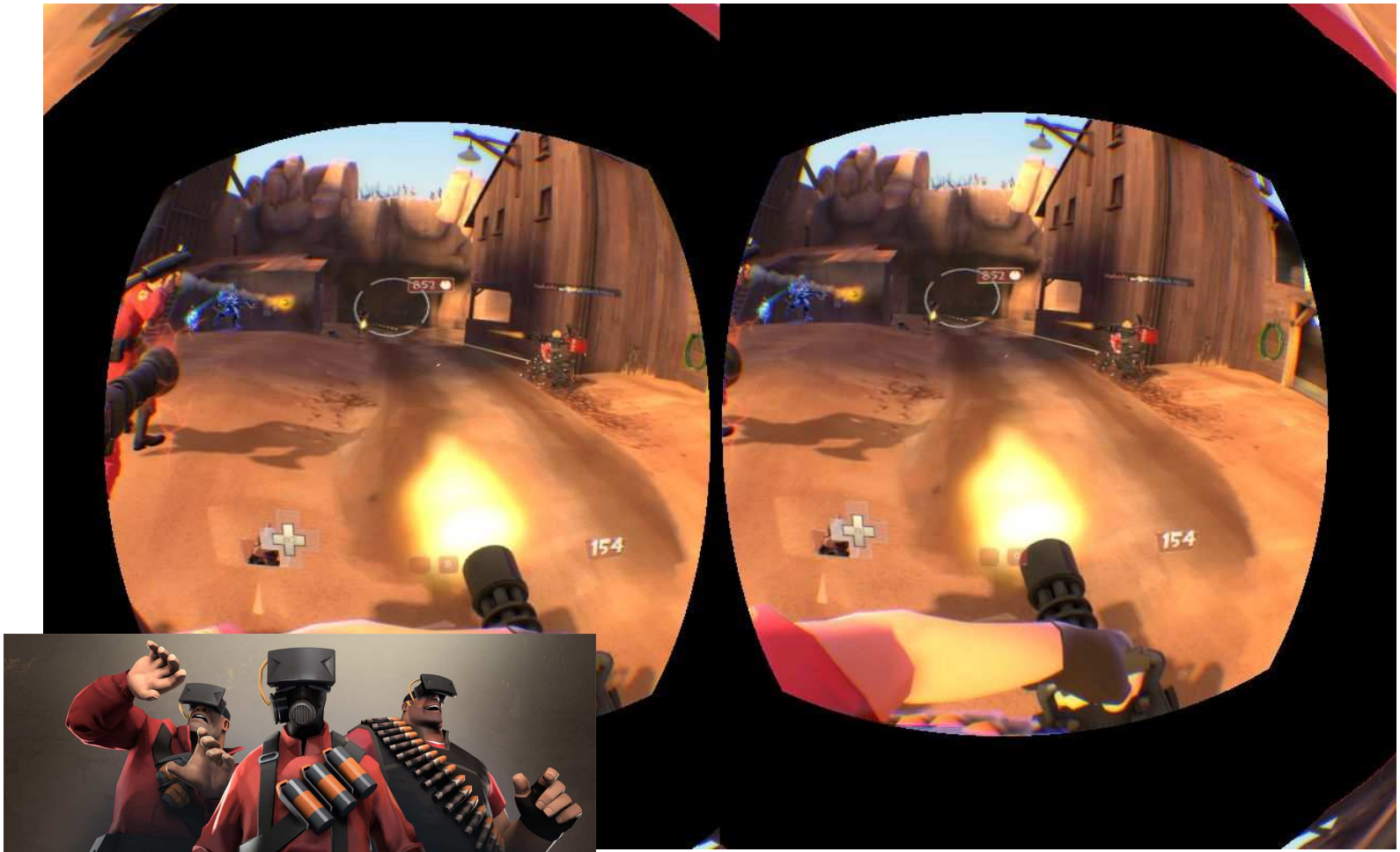
unity

UNREAL ENGINE

We need XRPUs, XR displays, XR software engines, and fresh ideas!

Biggest blind spot: Human perception and physiology

Immersive Video Games



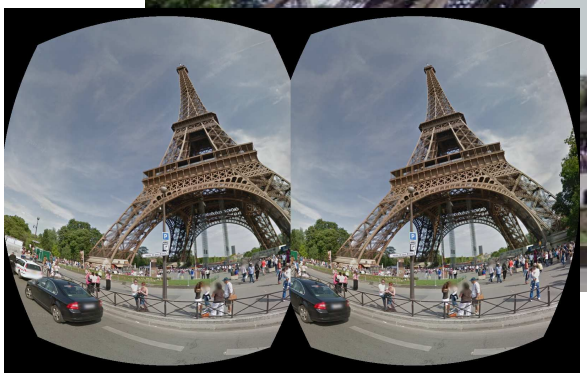
Team Fortress 2, Valve Inc.

Highly Original Games

A VR Game Jam Entry from DePaul University:

What could you do with an elephant trunk?

Panoramas



Pick your favorite street views and have a look around.

Augmented Street View

Jaunt Immersive Video

On Stage With Paul McCartney

Empathy

Chris Milk makes panoramic videos for the UN

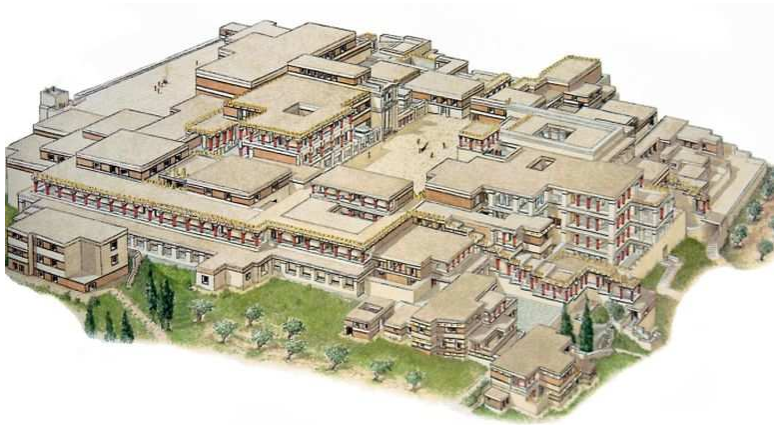
Consider comfort and perception of depth under various rendering schemes.

A Virtual Movie Theater

A private virtual movie theater, by Joo-Hyung Ahn

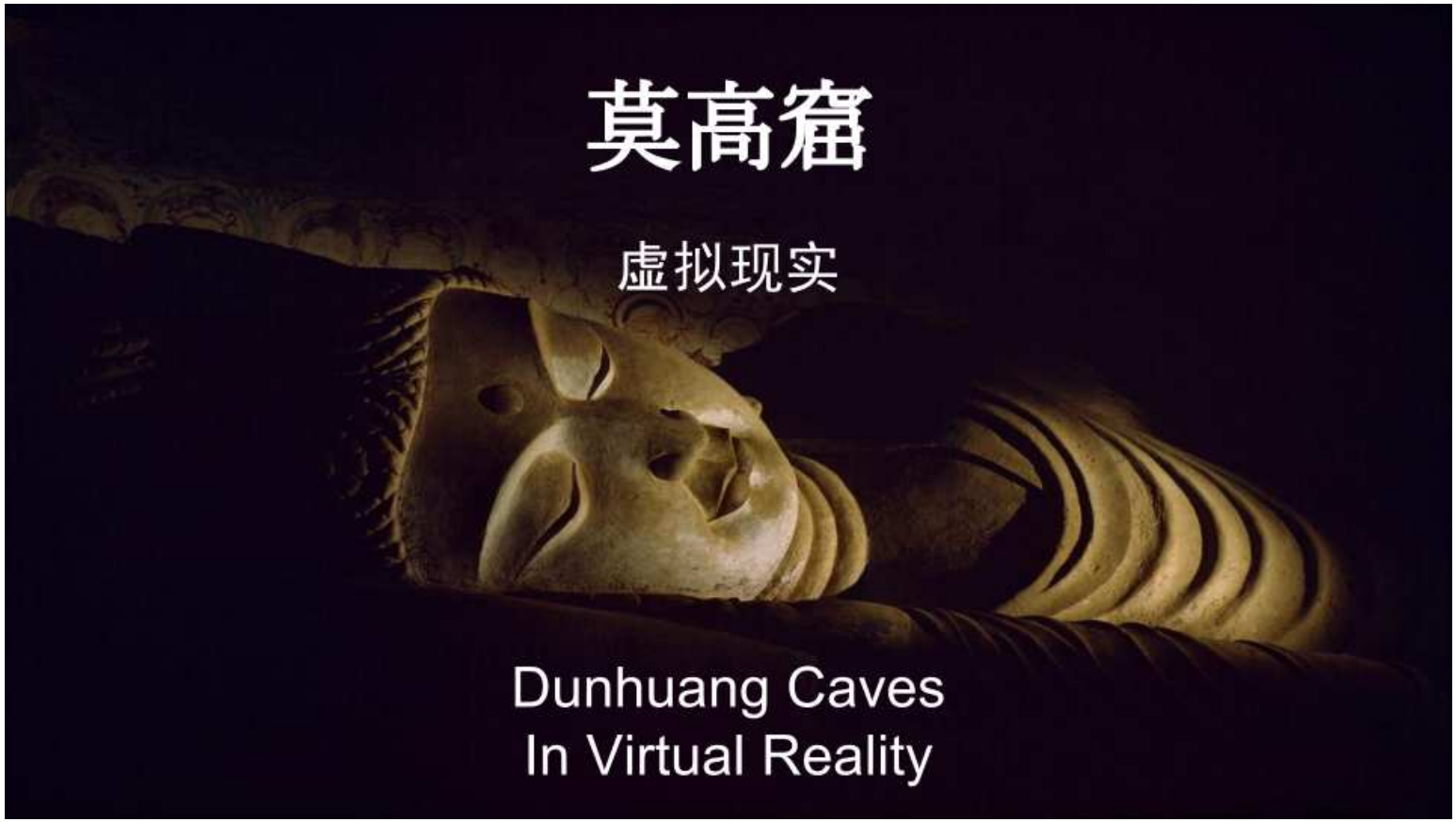
Two important cases:

- The site exists, but visitation is limited and/or it might be hard to preserve.
- The ruins exist, but virtual reconstructions are possible.



Avoid the Sir Arthur Evans controversy

Explore the Dunhuang Mogao Caves



UNESCO World Heritage Center

Difficult to reach, difficult to preserve

A Photograph

A 3D Scanned Model

A View of the Virtual World

Communicating Designs

By designer Olivier Demangel

Connect to Robots

Robots are becoming cheaper, smaller, and more powerful.

Health Care

- Training surgeons through first-person perspective
- Reducing stress on patients
- Exposure therapy
- Visualization of scans to prepare for surgery

Medical Training

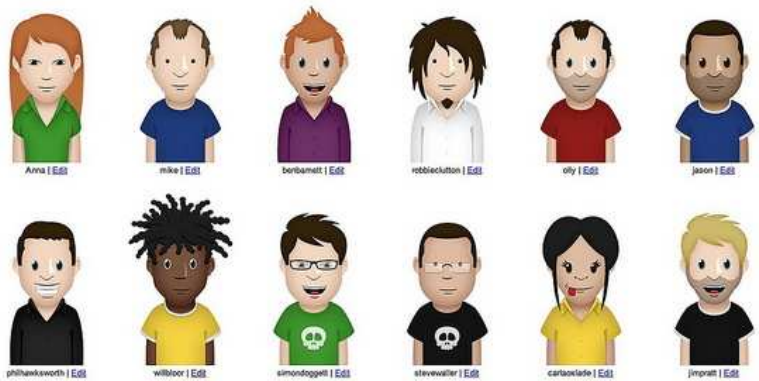
VimedixAR using Microsoft Hololens

Socializing

Telecommunication

Education, family functions, entertainment

Transformed social interaction (Bailenson)



- How much of a person needs to be captured?
- Enabling **better-than-usual** interaction
- Connections to avatars based on race, gender, height
- Beware of the uncanny valley

Flying Like in Your Dreams

Zurich University of the Arts

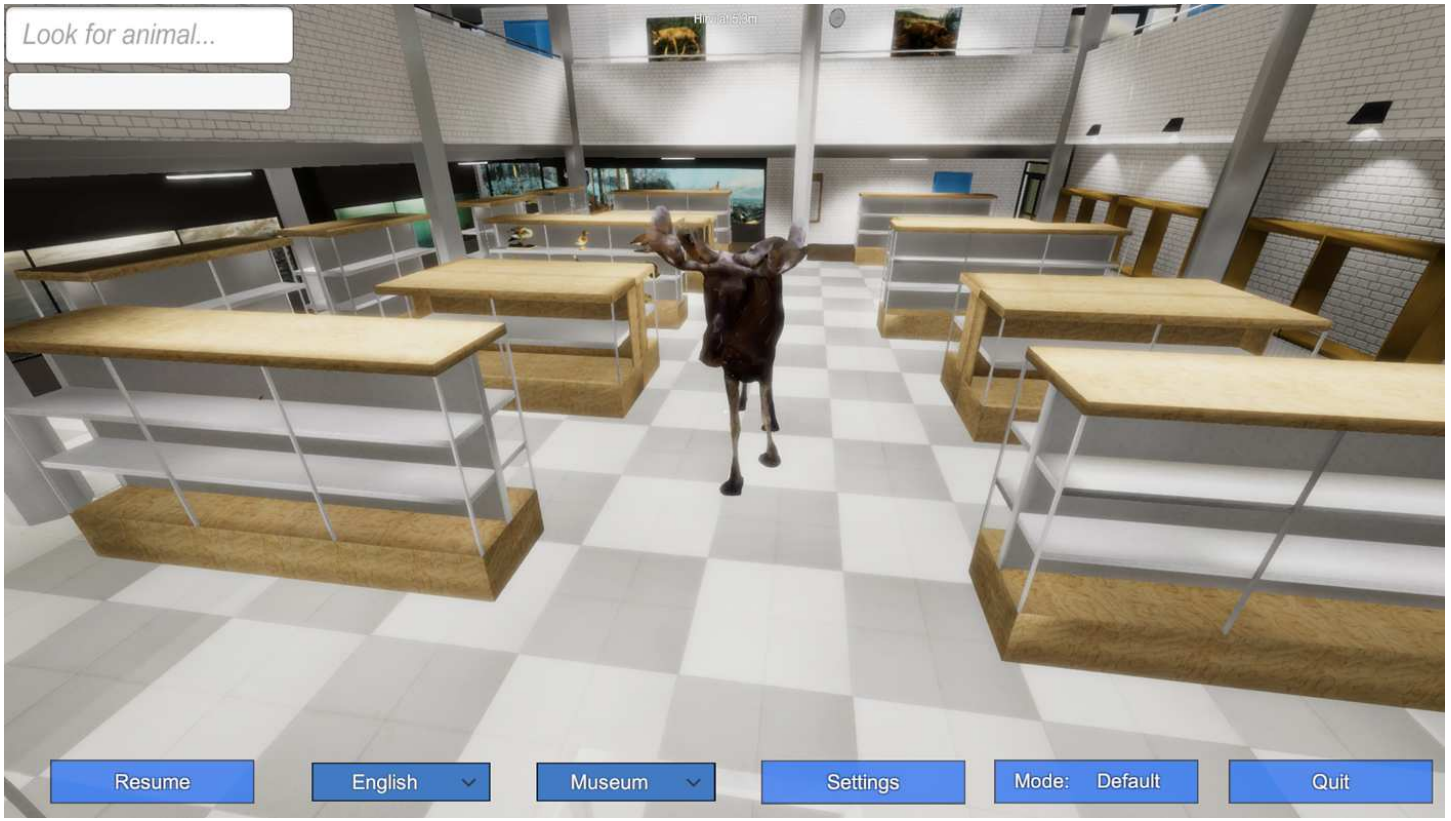
An Oulu Story

The Zoological Museum at University of Oulu until 2017

At the Center for Ubiquitous Computing:

- Animals have been carefully 3D scanned.
- Children can visit a virtual museum of the animals.
- Teleportation to the virtual wild or other fantasies

Virtual zoological museum



Virtual zoological museum

Virtual Oulu Library

Matti Pouke, Johanna Ylipulli, Ilya Minyaev, Paula Alavesa, Toni Alatalo, Timo Ojala

Problems

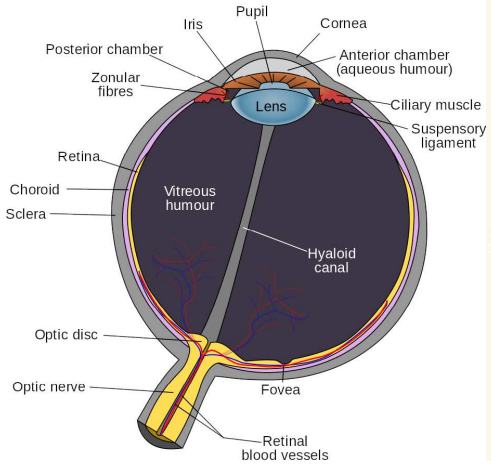
Think about what kind of networks you will need to support XR.

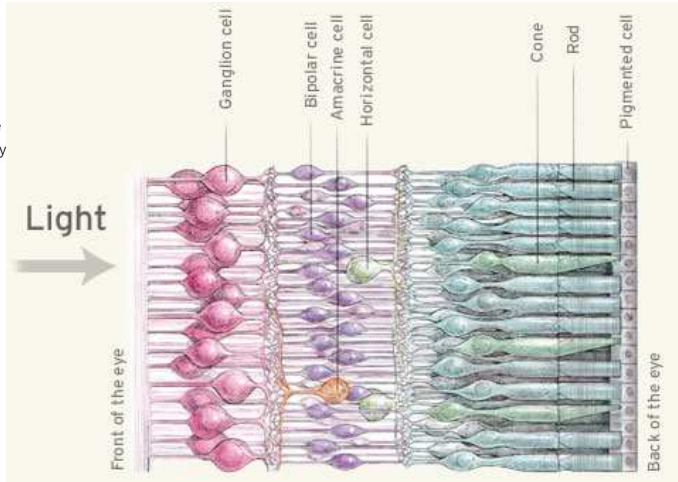
- Maintaining complex graphical worlds, simulated physics
- Interaction with worlds, and people connected to worlds
- Panoramic video streaming and interaction
- Maintaining mixed worlds: graphics and images overlaid

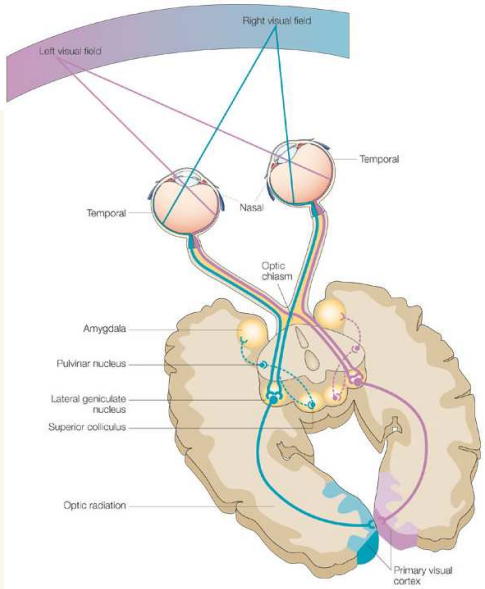
Human Physiology and Perception

- The processes are largely invisible to us
- Are we the scientist or lab rat?
- We adapt on all scales

Challenge: Reverse engineering the human

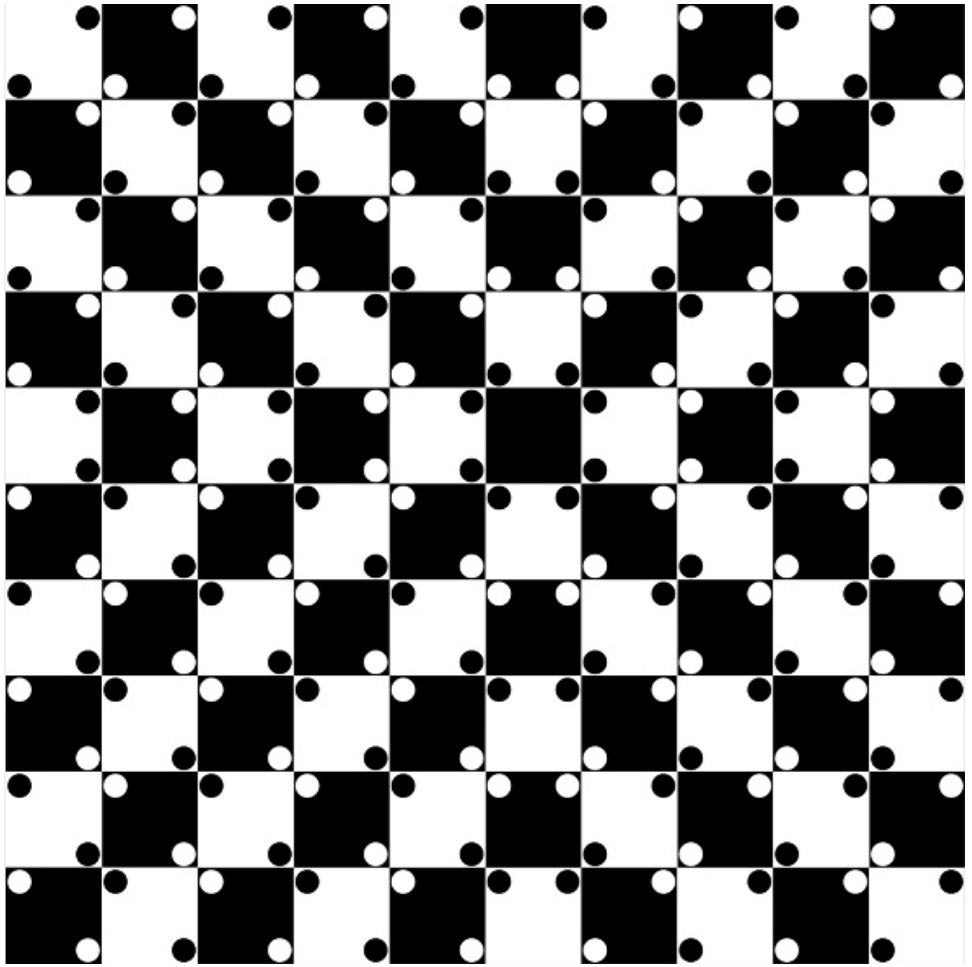




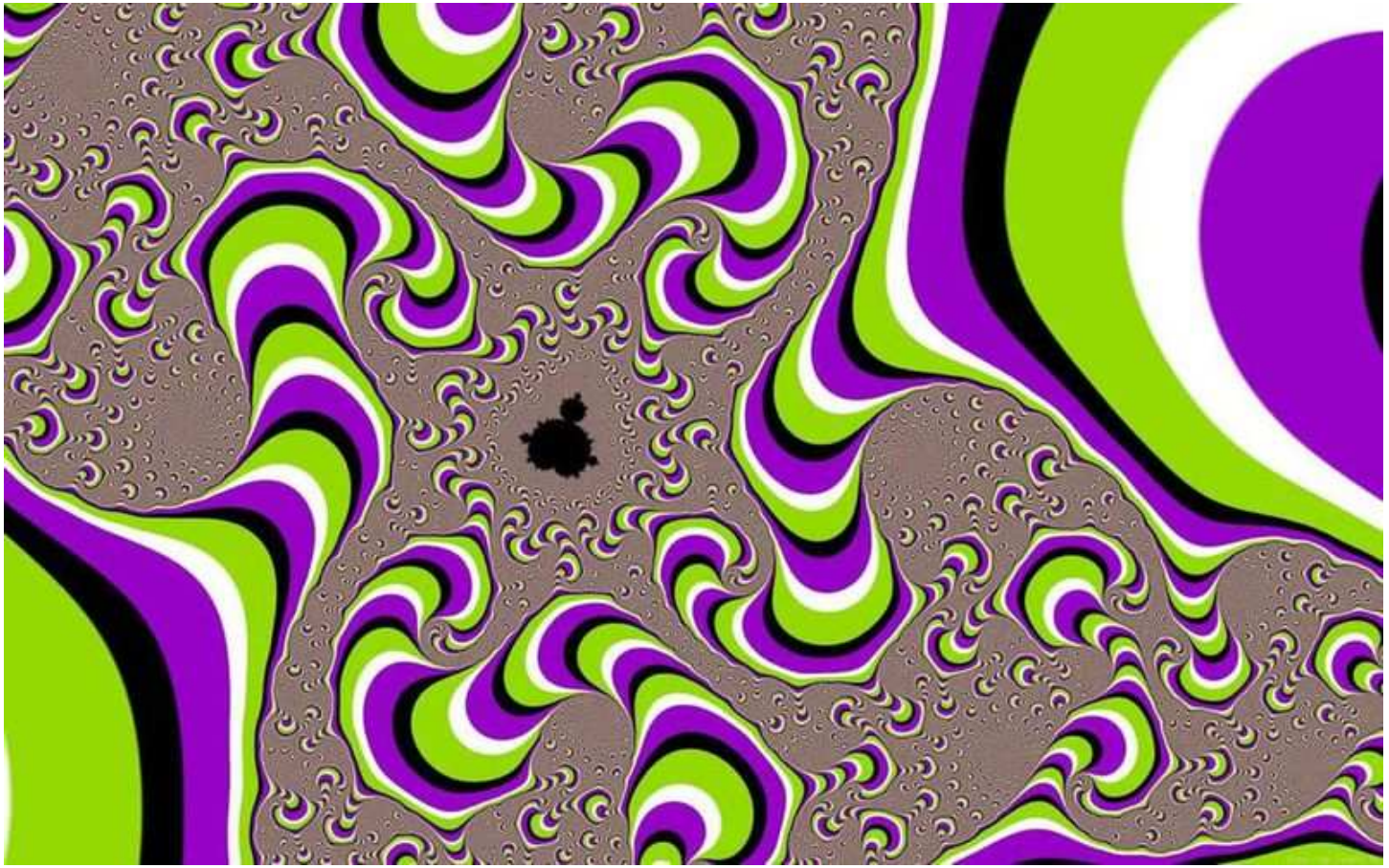


Human Physiology and Perception

Invisible processes at work: How do we infer depth?



Invisible processes at work: Why don’t the lines look straight?

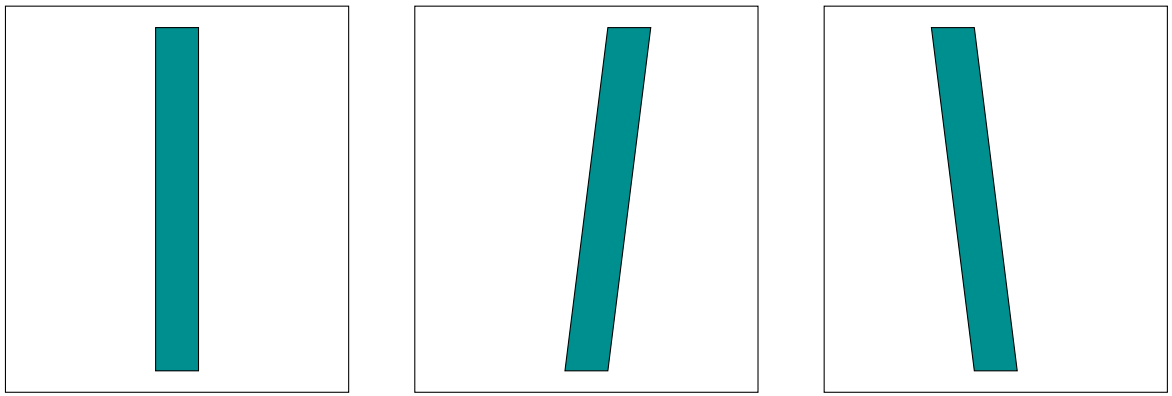


Invisible processes at work: Why do we incorrectly infer motion?

A “Simple” Challenge for VR Headsets

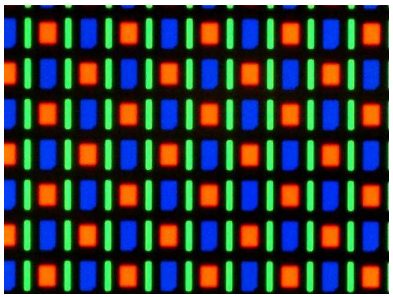
The *perception of stationarity*.

- TV screen vs. HMD screen
- HMD: Need to account for inverse viewpoint transform
- Need prediction to overcome tracking latency
- Optical distortion in periphery
- Pixel switching speeds and perceived blur
- Line-by-line display scanout
- Perceived judder and flicker

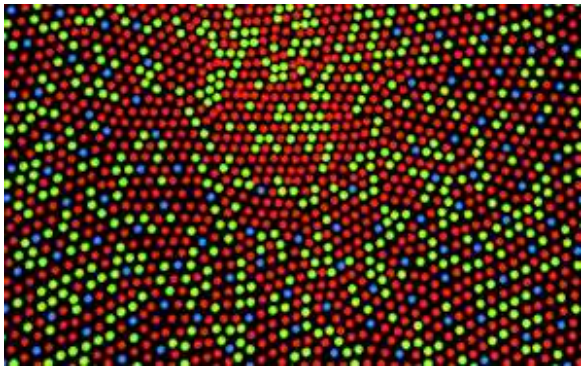


Beware of the vestibulo-ocular reflex (VOR)!

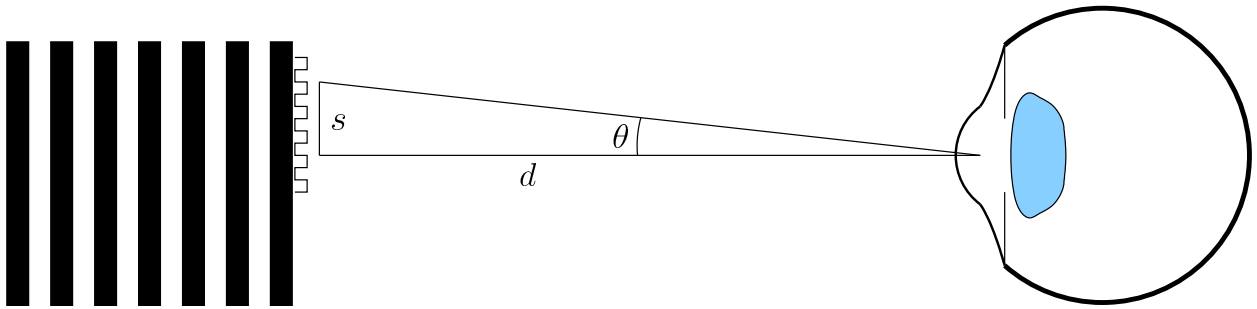
How Much Pixel Density Is Enough?



Pentile display

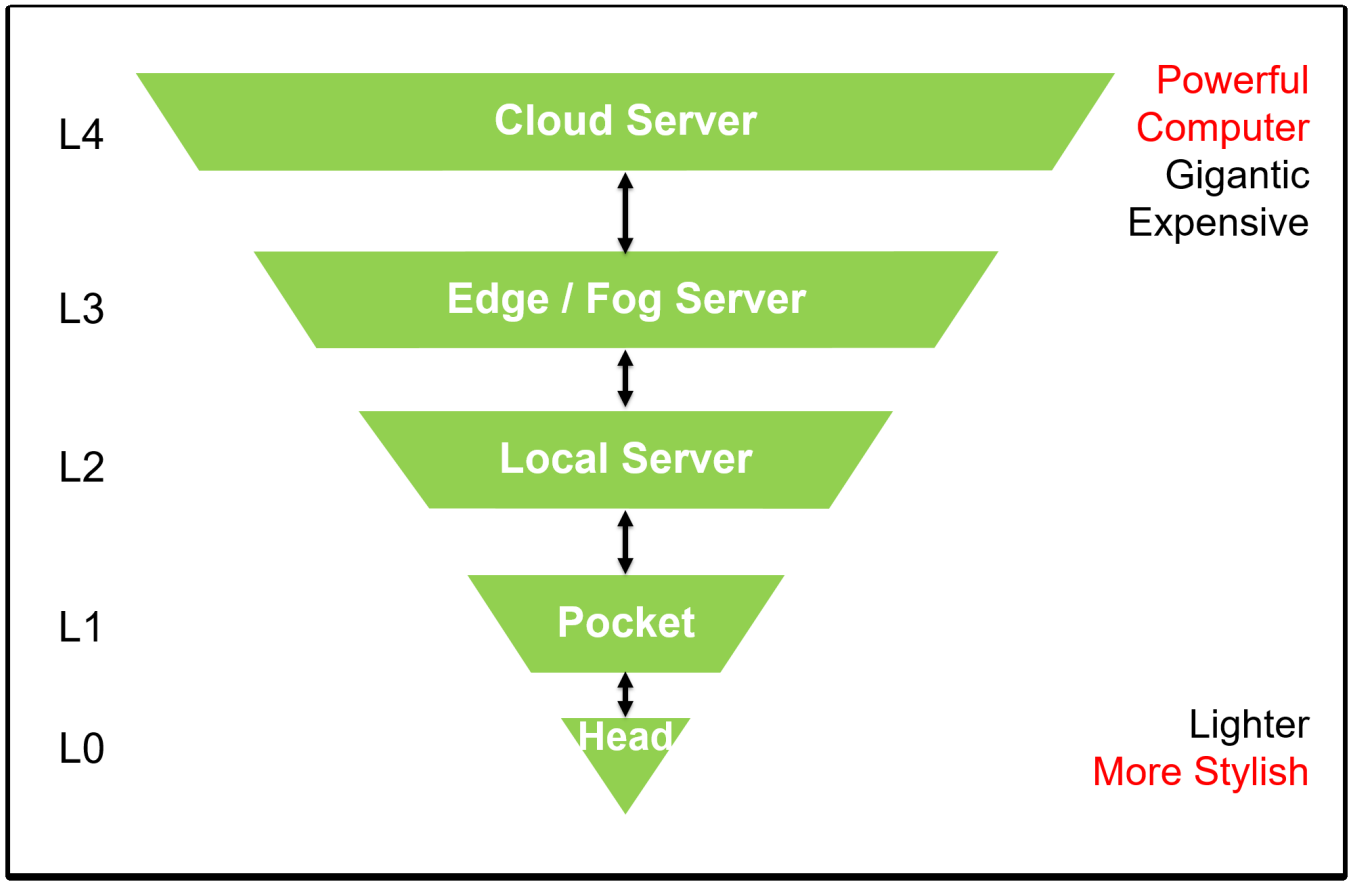


Photoreceptor mosaic



60 pixels per degree should be “enough”

Distributed XR



Keep hot, powerful computers away from your face!

Wireless VR: Current Headsets

What if we wirelessly stream to a wearable screen?
Oculus Rift, HTC Vive Pro

- 2 eyes
- 1440x1600 pixels per eye
- 24 bits per pixel
- 90 frames per second

Approximately 10 Gbit/s
HP Copper: 2160x2160 per eye $\rightarrow$ 20 Gbit/s

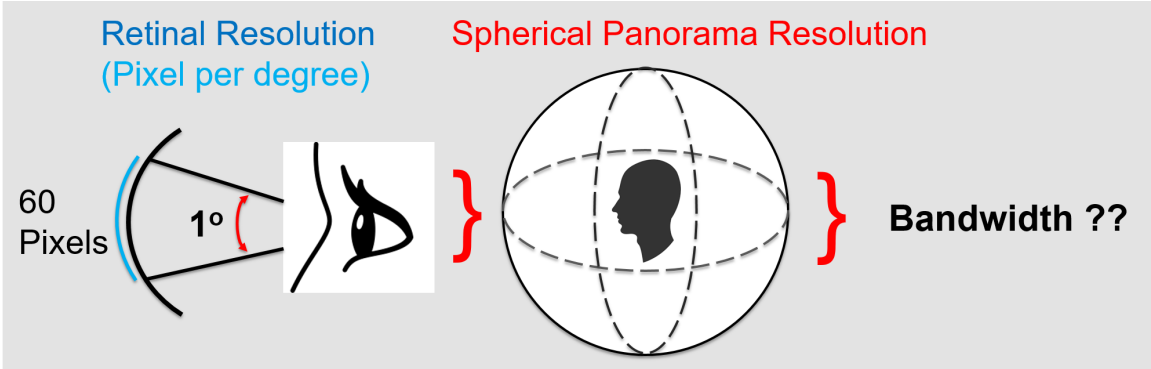
Wireless VR: Ideal Headsets

What if we wirelessly stream to a wearable screen?
(Calculations from Rafal Mantiuk, Cambridge Univerity, IEEE VR 2019)

- 2 eyes
- 150x170 FOV
- 60 pixels per degree
- 24 bits per pixel
- 120 frames per second
- 6 depth planes

Approximately 3.2 Tbit/s
Compression of depth planes? Higher frame rates? Dynamic range?

Retina Resolution Panorama Stream



Bandwidth requirements

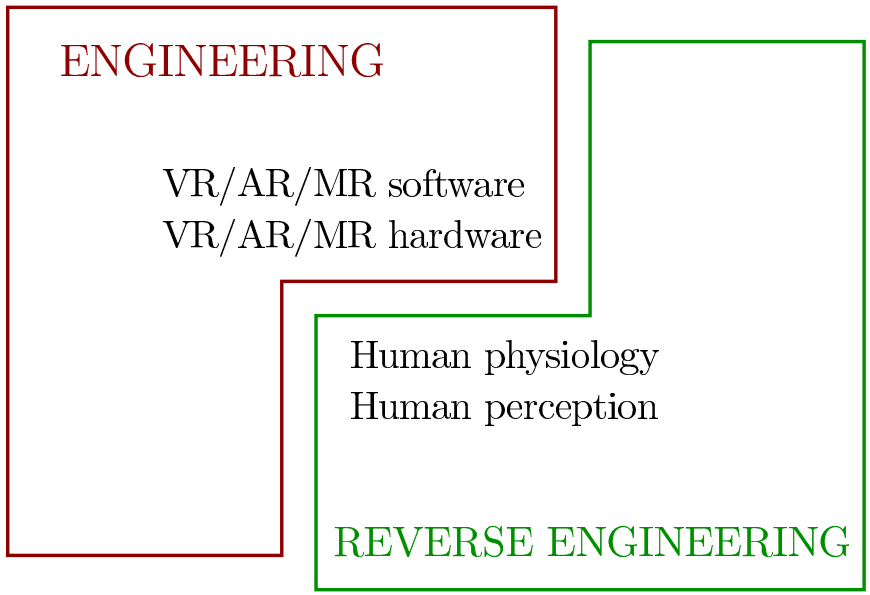
Retina Resolution Panorama Streaming Requirements				
ppd / fps	10	30	60	Note
30	3	27	107	Gbit/s
60	6	53	214	
100	10	89	356	
1000	100	891	3564	

Issues

- Obviously develop coding/decoding methods
- Compare to video compression: lossless 5-10x, lossy 20-200x; higher perceptual demands for XR
- Perception of stationarity leads to very low latency requirements
- Burstiness could be catastrophic; need recovery behaviors
- VR-specific reductions via foveated rendering, head prediction; double-edged sword
- Can accurate stochastic models be made of network aberrations?

Moved in August 2018 to Oulu, from UIUC

Part of Center for Ubiquitous Computing & AofF Flagship 6Genesis



Building new Perception Engineering Lab

Forming “unholy alliances” across Finland to advance XR

Unite people under perception-based criteria

Strong robotics component

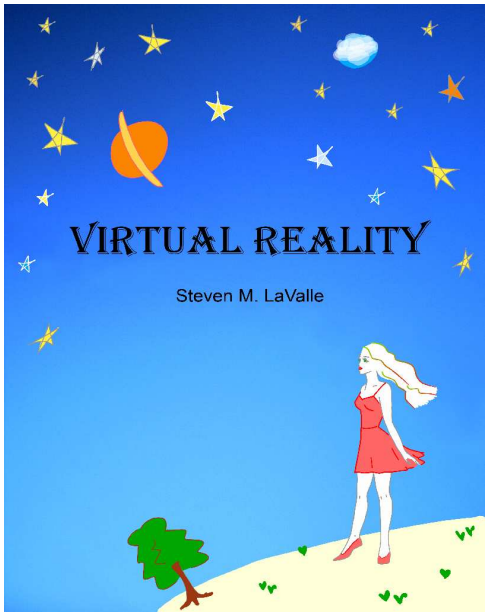
Free VR Book

Human Perception and Physiology

\+

Software and Hardware **Engineering**

VR book:



Download for free: **http://vr.cs.uiuc.edu/**

To be published by Cambridge U. Press

Also: Free Indian MOOC from NPTEL