The Future ... and Virtual Reality

CS 61B Spring 2016: Final Discussion

Agenda

--> Donuts

Announcements

Upper Division Overview

Special Topic: Virtual Reality / Augmented Reality / Mixed Reality

Final Words

Announcements

Homework 5 (Seam Carving) due Wednesday 4/27

Neat application in image processing (a research interest of mine)!

There might or might not be stuff happening during dead week... TBA.

Upper Division Overview

Slides are not an accurate representation of everything I will mention aloud.

CS Course Map

core hardware software theory applications

188

70

Required ——→

Recommended - - - -▸

Upper Division Overview

Very general overview. Lots of details left out.

Probably biased.

Ask me offline if you'd like to talk more about course selection!

Upper Division Overview

EECS151: Digital Design & Integrated Circuits

- The layer between low-level programming and the computer hardware itself.

CS 152: Computer Architecture & Engineering

- Performance programming, compilers, operating systems.
- More low-level stuff.

Take 61C. If you like 61C, especially the CPU design and process part, you might like these two.

Upper Division Overview

CS160: User Interface Design (Human-Computer Interaction)

- Design concepts. Android programming.

CS161: Computer Security

- Practical and applicable in many different areas.
- Prevalent in the real world, but often underappreciated.

CS162: Operating Systems

- Usually considered a must-take for any CS/EECS major.
- Most computer scientists should know how operating systems work, no matter what their focus.

Upper Division Overview

CS164: Compilers & Programming Languages

- Gain a deeper understanding of how languages are designed and how they are compiled and interpreted. If you found writing the Scheme interpreter interesting, this might also be interesting.

CS168: Internet Architecture

- How do we design large-scale distributed networks?
- How does the Internet even work as well as it does? What's wrong with it and what's great about it? How can we improve it?
- Practical; definitely recommend having some basic understanding of networking regardless of focus.

Upper Division Overview

CS169: Software Engineering

- Software engineering principles. Work on big software engineering group projects.
- Commonly said to be redundant if you've worked in large groups for other CS courses or done an internship.

CS170: Algorithms

- Computer science theory, algorithms, reasoning about how we solve problems (or if we can even solve them) and analyzing those solutions.
- Also considered fairly core for any computer scientist.

Upper Division Overview

CS172: Complexity and Computability

- Further exploring the complexity of problems and whether or not we can compute things.

CS174: Combinatorics and Discrete Probability

- More mathy and theoretical side of CS.

CS184: Computer Graphics

- How do we render and model computer images? Animation. Imaging. Pretty pictures. Involves math.

Upper Division Overview

CS186: Database Systems

- Theory and concepts behind databases; how do we efficiently and effectively design databases for various purposes? Data is the core of many CS applications. Practical background knowledge.

CS188: Artificial Intelligence

- Commonly regarded as a friendly earlier upper division course to take.
- Modeling AI. Think game search trees, alpha-beta pruning. Involves math.

Upper Division Overview

CS189: Machine Learning

- Subfield of AI. Developing models from real data, so that machines can use these models to do intelligent things. Hot topic in industry; lots of companies applying ML to their products. Involves math.

CS194-???: Special Topics courses

- Image processing, data science, advanced operating systems, etc.
- Probably for later once you've taken some other upper divisions.

Virtual Reality

Virtual Reality

In the news

Virtual Reality industry to generate $2.3 billion revenues this year

Pulse Headlines - 15 hours ago

The industry of **Virtual Reality** (VR) would generate hardware revenues of up to $2.3 billion ...

2016 is the year of

Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)

Every major company is jumping into the VR/AR space.

It will happen with gaming first. But applications are endless.

Work, education, training, entertainment, simulations, etc.

You might not interact with VR directly, but it will definitely influence your lives in some way or another.

Many slides are borrowed from Prof. Ren Ng's Spring 2016 CS184 lecture.

Virtual Reality (VR) vs Augmented Reality (AR)

VR = virtual reality

- User is completely immersed in virtual world (sees only light emitted by display)

AR = augmented reality

- Display is an overlay that augments user's normal view of the real world (e.g., Terminator)

Image credit: Terminator 2 (naturally)

VR Head-Mounted Displays (HMDs)

Oculus Rift

Sony Morpheus

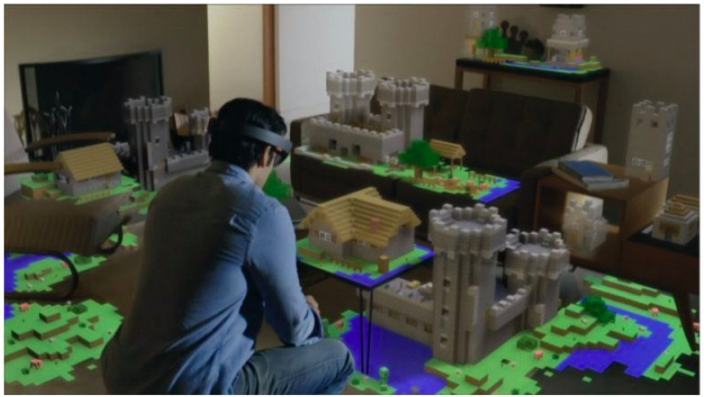
HTV Vive

Google Cardboard

AR Headsets

Microsoft Hololens

Meta



Field of View

Regular 2D panel displays have windowed FOV

- User orients themselves to the physical window of the display

VR/AR displays provide 360 degree FOV

- Displays attached to head
- Head orientation is tracked physically
- Rendered view synchronized to head orientation in realtime (much more on this later)

3D Visual Cues

Panel displays give 3D cues from monocular rendering

- Occlusion, perspective, shading, focus blur, …
  - Uses z-buffer, 4x4 matrices, lighting calculation, lens calculations…

VR/AR displays add further 3D cues

- Stereo: different perspective view in left/right eyes
  - Physically send different images into each eye
- Parallax (user-motion): different views as user moves
  - Uses head-tracking technology coupled to perspective rendering

VR Gaming

Bullet Train Demo (Epic)

VR Video

VR Video

VR Teleconference / Video Chat

http://vrchat.com/

Challenges of Virtual Reality

Many difficult technical challenges:

- Display technologies
- Very precise tracking of head, face, and body position
- Haptics (simulate touch)
- Sound synthesis
- User interface challenges
- Creating content in VR is different than for a normal 2D display
- And more...

VR Headset Components

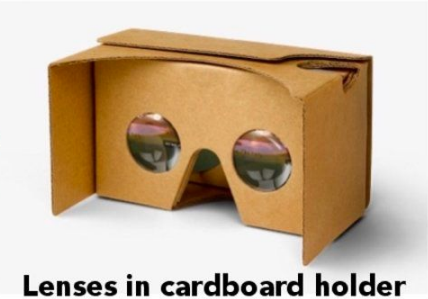
Google Cardboard

Use mobile phone display inside inexpensive headset with lenses

- Use phone's camera and gyro for tracking view direction
- Stereo 360 degree experience, no head-motion parallax

Mobile phone display

Phone camera used for tracking head position



Lenses in cardboard holder

Image credits: slashgear.com, Google

Oculus Rift

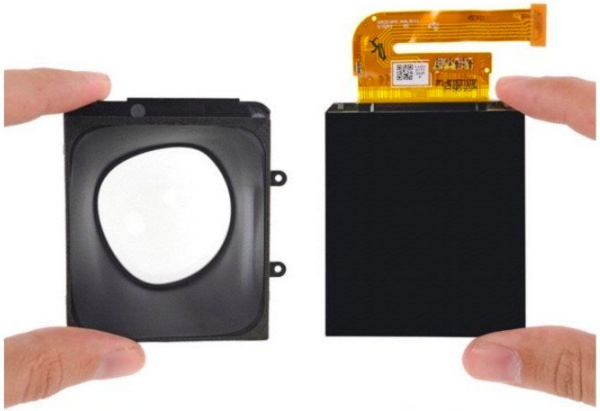


Image credit: ifixit.com https://www.ifixit.com/Teardown/Oculus+Rift+CV1+Teardown/60612

Oculus Rift

Image credit: ifixit.com

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Head Tracking

Head Tracking

We need to track the position and orientation of the head and eyes in order to render views correctly and realistically.

Requires high accuracy (less than 1mm of error)!

Head Tracking: Google Cardboard

Track is done using rear-facing camera and built-in gyroscope to estimate the user’s viewpoint.

2D rotation tracking using gyroscope works pretty well.

3D positional tracking … more challenging.

Environment-Supported Vision-Based Tracking?

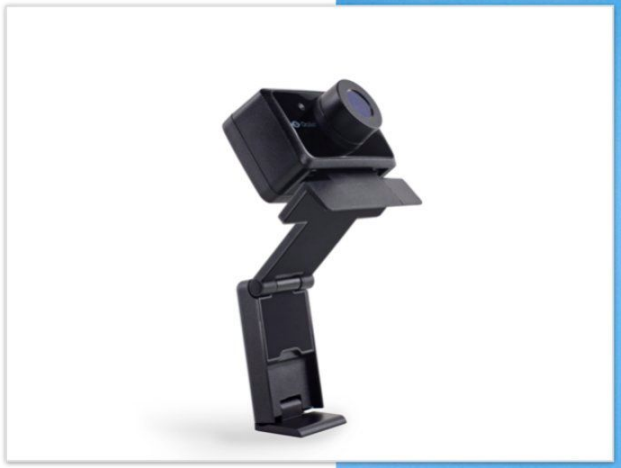
Image credit: gizmodo.com

Early VR test room at Valve, with markers positioned throughout environment

Oculus Rift IR LED Tracking System

Oculus Rift + IR LED sensor

Oculus Rift LED Tracking System (DK2)



External 60Hz IR Camera

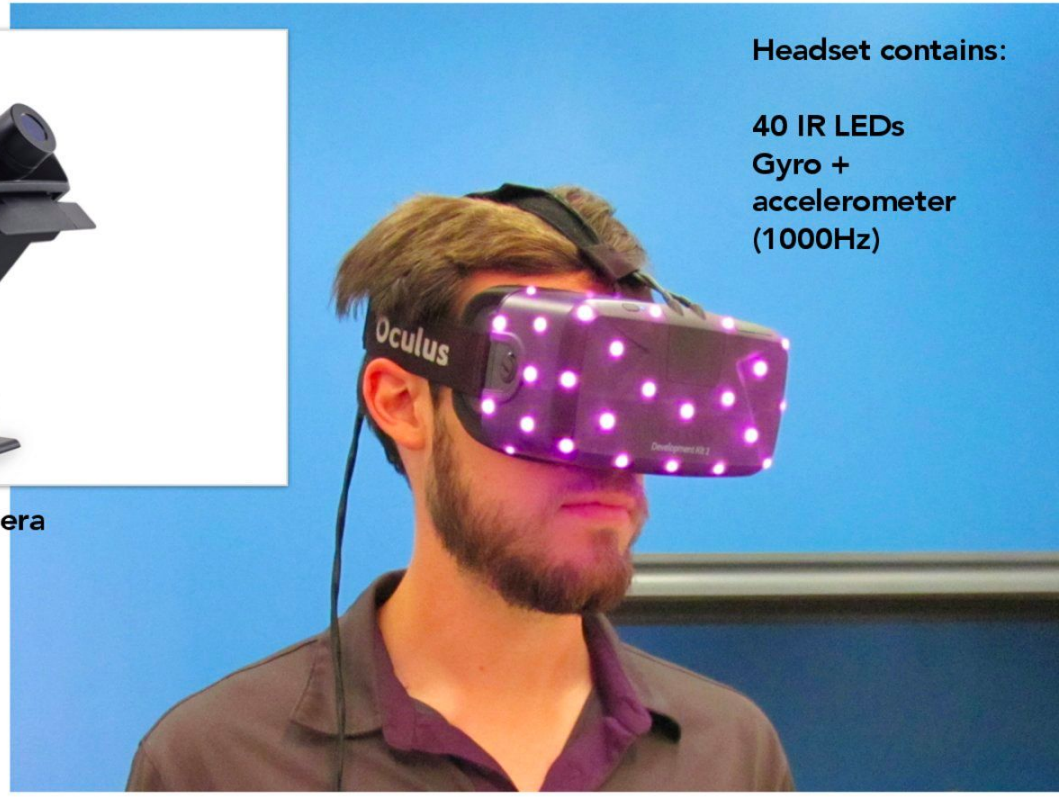
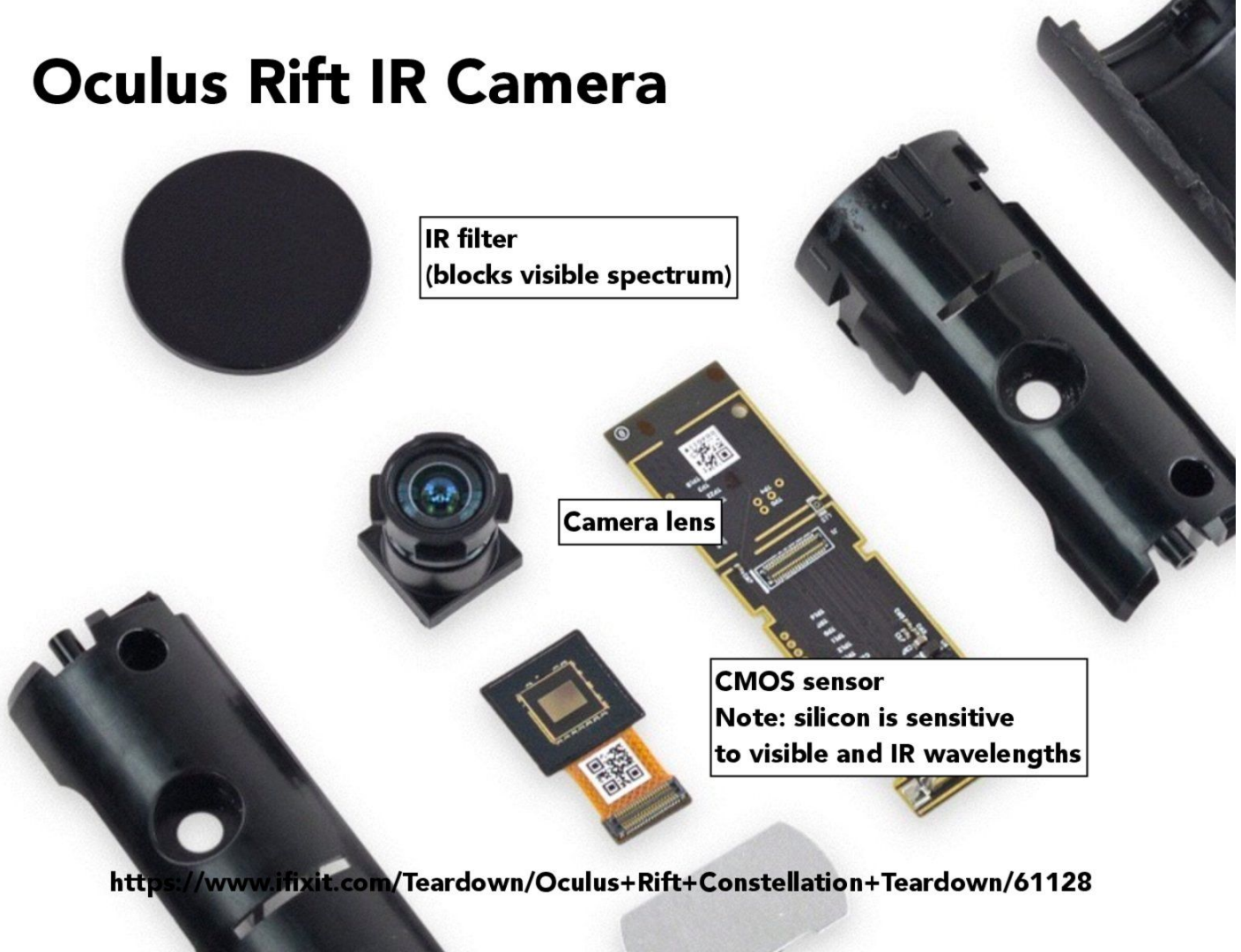


Photo taken with IR-sensitive camera (IR LEDs not visible in real life)

Image credit: ifixit.com

Oculus Rift IR Camera



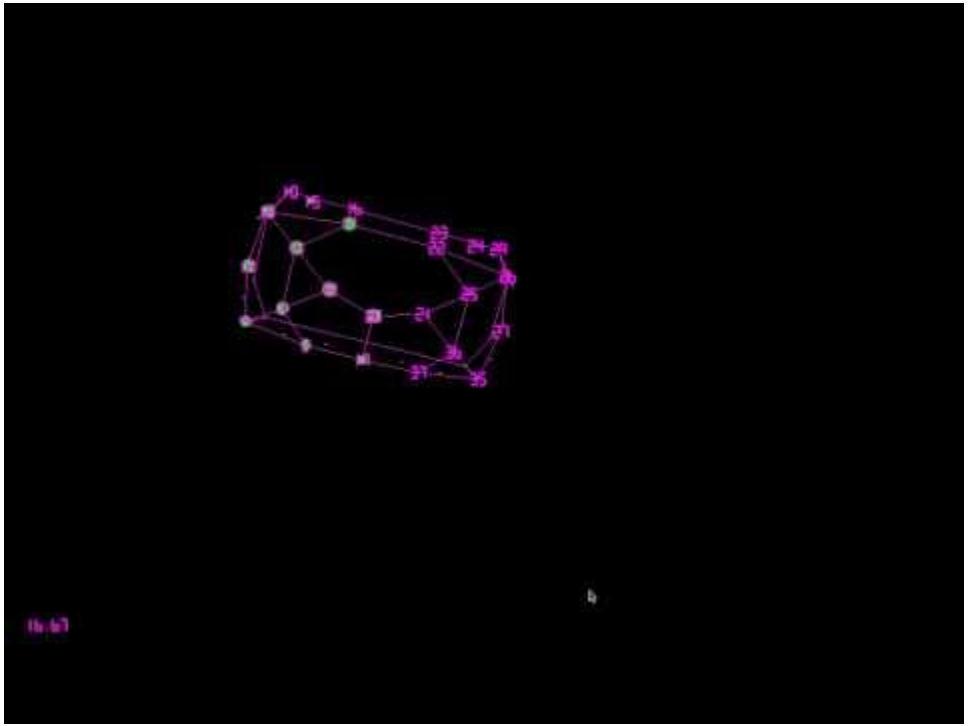
https://www.ifixit.com/Teardown/Oculus+Rift+Constellation+Teardown/61128

Head Tracking: Oculus Rift

Oculus Rift uses **active marker motion capture**.

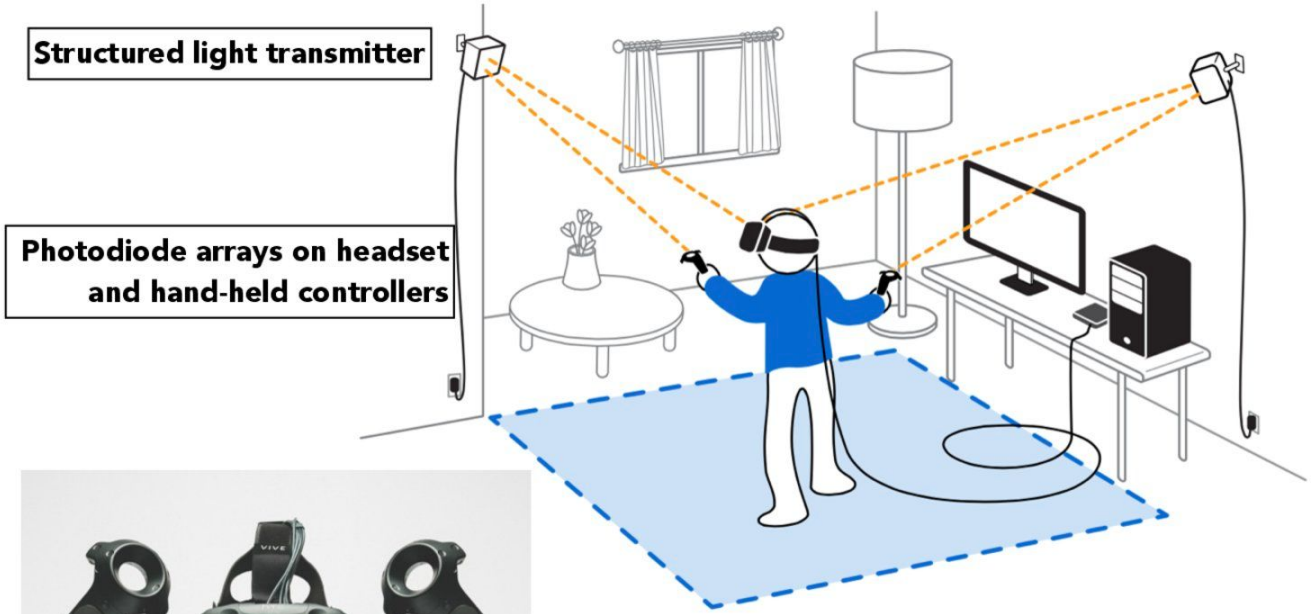
- LED markers on headset each emit unique blinking pattern.
- IR camera picks up the LED markers and determines the headset's position and orientation.

Head Tracking: Oculus Rift

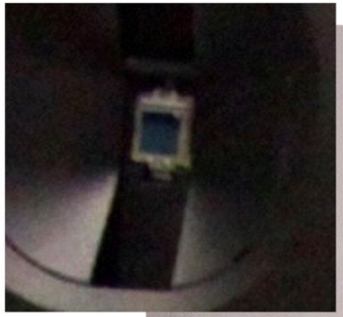


Credit: Oliver Kreylos, https://www.youtube.com/watch?v=X4G6_zt1qKY

HTC Vive Tracking System ("Lighthouse")



Vive Headset & Controllers Have Array of IR Photodiodes

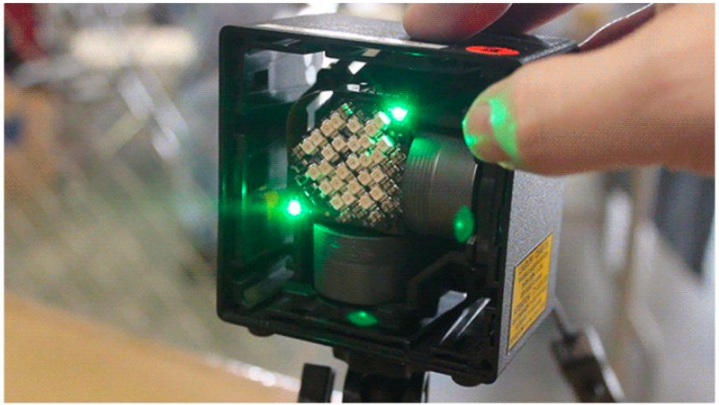


IR photodiode

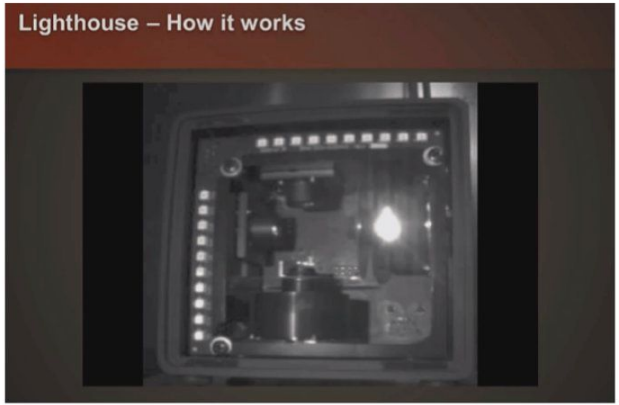
Image credit: uploadvr.com

(Prototype) Headset and controller are covered with IR photodiodes

HTC Vive Structured Light Emitter ("Lighthouse")



Light emitter contains array of LEDs (white) and two spinning wheels with lasers



Sequence of LED flash and laser sweeps provide structured lighting throughout room

Credit: Gizmodo: http://gizmodo.com/this-is-how-valve-s-amazing-lighthouse-tracking-technol-1705356768

HTC Vive Tracking System

For each frame, lighthouse does the following:

- LED pulse, followed by horizontal laser sweep
- LED pulse, followed by vertical laser sweep

Each photodiode on headset measures time offset between pulse and laser arrival

- Determines the x and y offset in the lighthouse's field of view
- In effect, obtain an image containing the 2D location of each photodiode in the world
    - (Can think of the lighthouse as a virtual "camera")

HTC Vive Tracking System (“Lighthouse”)

Credit: rvdm88 (YouTube), https://www.youtube.com/watch?v=J54dotTt7k0

HTC Vive

Credit: rvdm88 (YouTube), https://youtu.be/qYfNzhLXYGc

Head Tracking: Summary

Tracking methods:

- Camera on headset + computer vision + gyro (Google Cardboard)
- External camera + marker array on headset (Oculus Rift)
- External structured light + sensor array on headset (HTC Vive)

3D tracking and depth sensing is an active research area

- SLAM (Simultaneous Localization and Mapping) is an example
- Microsoft Hololens, Google Tango, Intel RealSense are example products doing SLAM

Challenges of Virtual Reality

Many difficult technical challenges:

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Rendering Challenges in VR

Challenge #1: Low Latency

The goal of a VR system to achieve “presence”, to trick the brain into thinking what it is seeing is real.

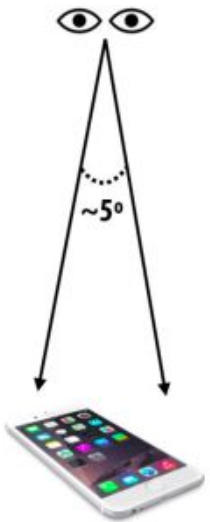
To do so, we require exceptionally low latency.

What you see must change as you move your head, as in real life.

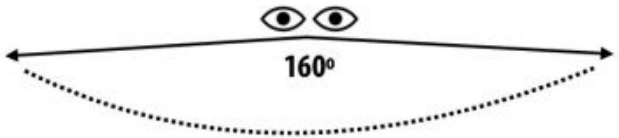
Latency goal in VR: 10 to 25 ms

- Need low-latency head tracking
- Need low-latency rendering and display

Challenge #2: High Resolution



iPhone 6: 4.7 in "retina" display:
1.3 MPixel
326 ppi → 57 ppd



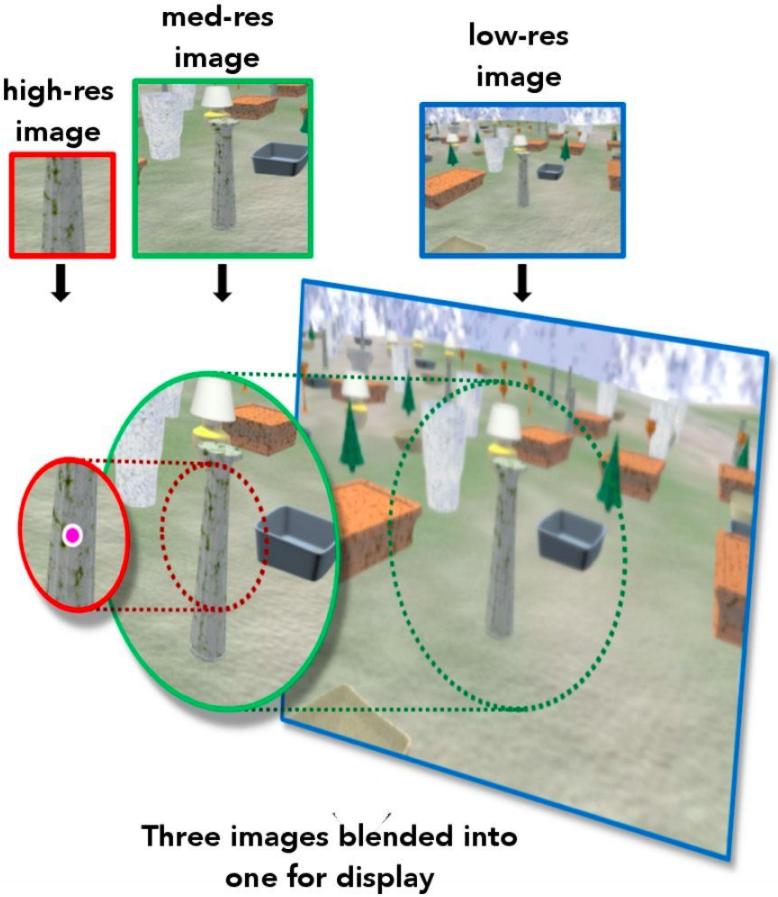
Human: ~160° view of field per eye (~200° overall)
(Note: does not account for eye's ability to rotate in socket)

Future "retina" VR display:
57 ppd covering 200°
= 11K x 11K display per eye
= 220 MPixel

Strongly suggests need for eye tracking and foveated rendering (eye can only perceive detail in 5° region about gaze point

Foveated Rendering

Idea: track user's gaze, render with increasingly lower resolution farther away from gaze point



Augmented Reality

Augmented Reality

In augmented reality (AR), the real world is augmented by an overlaid display.

This type of mixed reality is commonly considered to be much more challenging and the technology out there is still very expensive and very much in its infancy.

Microsoft Hololens, Magic Leap, ...

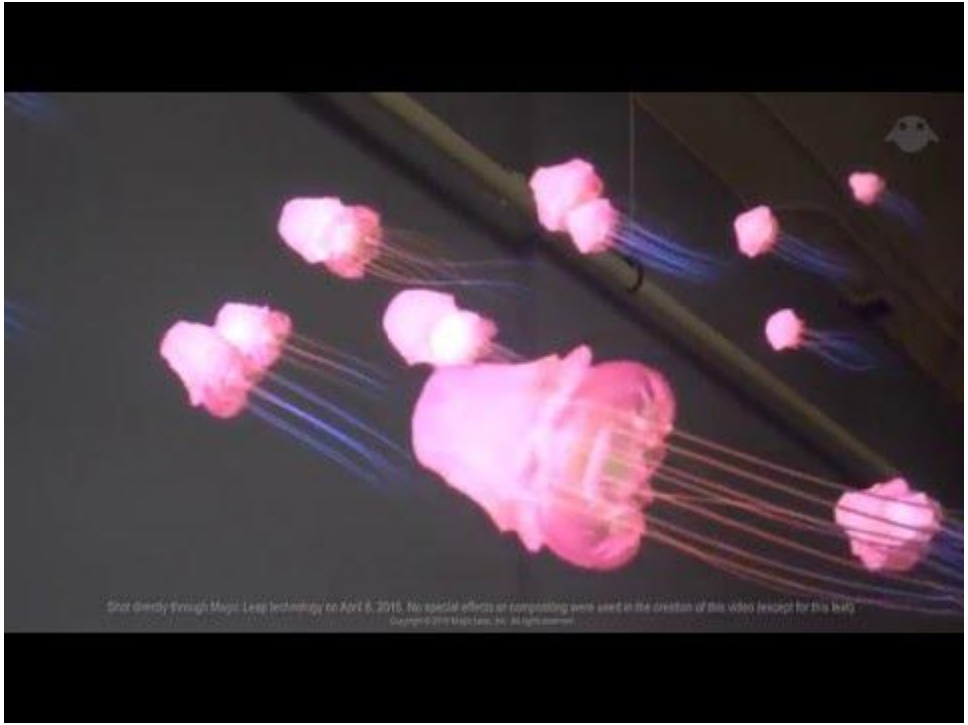
Microsoft Hololens

Credit: https://youtu.be/aThCr0PsyuA

Microsoft Research: Holoportation

Credit: https://youtu.be/7d59O6cfaM0

Magic Leap



Credit: https://youtu.be/GmdXJy_IdNw

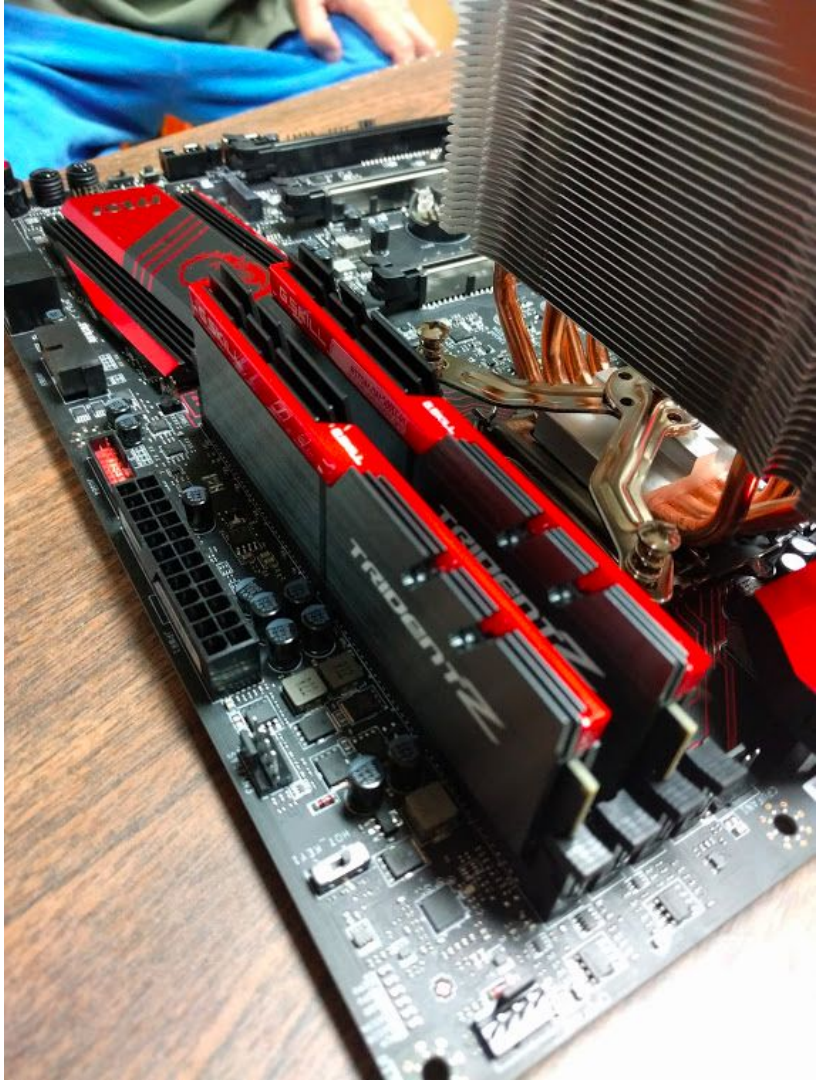
Excited about Virtual Reality?

I sure am.

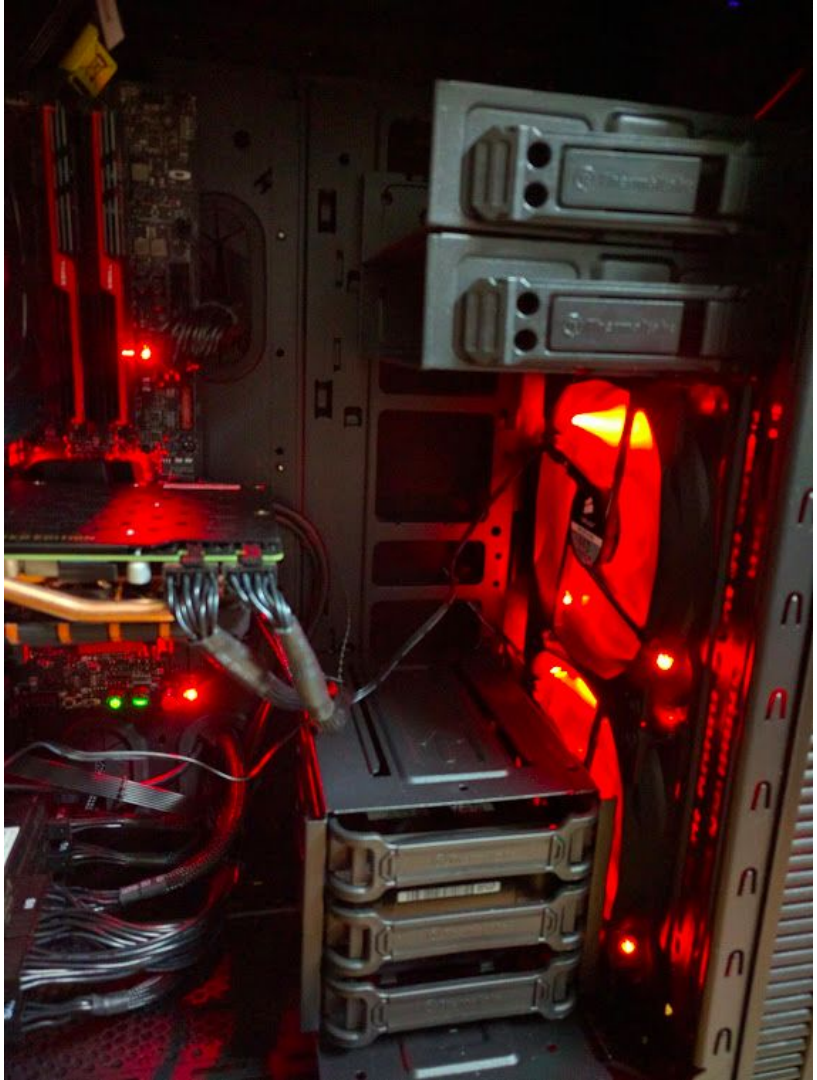
The real reason for this lecture topic is just so that I can geek out a bit and show the following in class.


msi


ZeroFrozr
Smart cooling,
Stay quiet
REMOVE
BEFORE
GAMING
msi
graphics card
GTX 980Ti


TRIDENT Z


msi
EVGA
850 G2
80



VIVE htc

It's in the works!

Thanks for pre-ordering the HTC Vive. Your order's being processed now.

Interested in Virtual Reality?

I'd love to chat about it! :)

Consider joining the VR@Berkeley club on campus.

http://vr.berkeley.edu

Our Mission

We seek to foster a community of Berkeley students, industry, and academia to increase public awareness of virtual reality (VR), provide developer resources and training, and promote dialogue about the applications and implications of VR. Our members receive training in cutting edge technology, develop on VR platforms, and explore the intersection of physical and virtual reality.

Interested in Virtual Reality?

If you haven't had the chance to try VR yet, **you definitely should**.

It is impossible for anyone to describe what the experience is like.

But it is **amazing** and **surprisingly realistic**.

VR@Berkeley commonly puts on demos with various VR headsets; keep an eye out for them on Facebook.

I occasionally help out with the demos, so come say hi. :)

Bring your friends!

Recent Articles in VR

“The Rise and Fall of Virtual Reality”
http://www.theverge.com/a/virtual-reality/

“The Untold Story of Magic Leap, the World’s Most Secretive Startup“
http://www.wired.com/2016/04/magic-leap-vr

Final Words

Final Words

You have learned so much in 61B this semester.

- You know about a plethora of data structures and algorithms central to computer science today.
- You know how to think about and solve different kinds of problems.
- You know how to write large, standalone programs.
- You know how to debug them.
- You know how to reason about complexity and problem solving.
- You can make silly computer science jokes and memes.
- You've achieved more in 61A and 61B than I did when I took those classes my freshman year. (61A and 61B are getting harder and harder!)

Be proud of your achievements in this class this semester.

Final Words

Thank you all for being an awesome class and consistently coming to section every week!

Thank you for a great (and potentially last) semester of teaching and learning.

Final Words of Wisdom (?)

College goes by fast.

Get out there and take advantage of what you have here on campus.

There's so much to learn and explore within an arm's reach.

Find out what you like and what you don't like.

Success in college isn't measured simply by your grades.

People are important.

College wouldn't be what it is without the people you experience it with.

Make friends and stay in touch with them.

Your experiences with your friends in college will be what you remember the most, not what grade you got in some class you took some semester.

You will support them, and they will support you.

Final Words of Wisdom (?)

People don’t have a clue what they’re doing with themselves.

Even if they look like they do. Seriously.

I thought I knew exactly what I was going to do when I came here, but I’ve re-routed and re-directed myself more times than I could count.

So keep an open mind and follow whatever interests you or whatever you care about the most.

People are naturally afraid of uncertainty.

Try to embrace uncertainty and accept that things change over time.

Change is **good**.

You will continuously course-correct yourself until you eventually get to your desired destination, whatever that may be (also always changing).

Final Words of Wisdom (?)

Push yourselves.

- This is the busiest time of your lives.
- Challenge yourselves to improve.
  - This is what your friends are for, too.
- Find your limits. I found mine this semester.

Have fun!

- Make time for relaxing.
- Browse dank memes.
- Perhaps even create dank memes. :^)

Goodbye!

Feel free to stay in touch: Email, Facebook, etc.
Always happy to chat about anything.