EE 267: Introduction and Overview

Gordon Wetzstein
Stanford University

EE 267 Virtual Reality
Lecture 1

stanford.edu/class/ee267/
About Me

2003

VR Lab
Prof. Bernd Froehlich
Bauhaus University Weimar, Germany
~60 Projects on Cameras & Displays between 2003-2017
Oculus DK2 @ SIGGRAPH 2013
Oculus VR

Microsoft Hololens
simulation & training

visualization & entertainment

gaming

robotic surgery
Consumer Applications – Prescription Glasses
A Brief History of Virtual Reality

Stereoscopes
Wheatstone, Brewster, ...

VR, AR,
Ivan Sutherland

VR explosion
Oculus, Sony, Valve, MS, ...

AR Displays
A Brief History of Virtual Reality

1838

1916

1968

1995

2012-2016

Nintendo Virtual Boy

VR explosion
Oculus, Sony, Valve, MS, …

AR Displays

“HMD”
Nintendo Virtual Boy

- 770,000 units sold, commercial failure – judge for yourself

Game: Red Alarm
1968

1980s

2000s

electronic / digital

HCI / haptics

low cost, high-res, low-latency!
Ivan Sutherland’s HMD

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

I. Sutherland “A head-mounted three-dimensional display”, Fall Joint Computer Conference 1968
Oculus DK2 Teardown

key factors:
low latency & wide fov!

- Samsung 5.7" AMOLED: 1920x1080px, 75Hz
- 2 sets of lenses (for different prescriptions)
- InvenSense 6-axis IMU
- ARM Cortex-M3 MCU
- …
Field of View!
Oculus DK2 Clones

- Oculus Rift
- Sony Morpheus
- DuroVis Dive
- VrAse
- Zeiss Cinemizer
- Avegant Glyph
- Hasbro My3D
- Altergaze
Google Glass small!
Pepper’s Ghost 1862
Microsoft Hololens – Time of Flight Sensor Array
Google Project Tango – SLAM / 3D Scanning
Taxonomy of Direct 3D Displays:

Glasses-bound vs. Unencumbered Designs

**Glasses-bound**
- **Stereoscopic**
  - Immersive (blocks direct-viewing of real world)
  - See-through (superimposes synthetic images onto real world)
- **Multiplexed** (stereo pair with same display surface)
  - Spatially-multiplexed (field-concurrent) (color filters, polarizers, autostereograms, etc.)
  - Temporally-multiplexed (field-sequential) (LCD shutter glasses)

**Unencumbered**
- **Automultiscopic**
  - Parallax-based (2D display with light-directing elements)
    - Parallax Barriers (uniform array of 1D slits or 2D pinhole arrays)
    - Integral Imaging (lenticular sheets or fly’s eye lenslet arrays)
  - Volumetric (directly illuminate points within a volume)
    - Multi-planar (time-sequential projection onto swept surfaces)
    - Transparent Substrates (intersecting laser beams, fog layers, etc.)
  - Holographic (reconstructs wavefront using 2D element)
    - Static (holographic films)
    - Dynamic (holo-video)

Taxonomy adapted from Hong Hua
Taxonomy of 3D Displays:

Immersive Head-mounted Displays (HMDs)

- **Glasses-bound**
  - Stereoscopic
  - Multiplexed (stereo pair with same display surface)

- **Immersion** (blocks direct-viewing of real world)

- **Head-mounted**
  - (eyepiece-objective and microdisplay)
Taxonomy of 3D Displays:

**See-through Head-mounted Displays (HMDs)**

- **Glasses-bound**
- **Stereoscopic**
- **Multiplexed**
  - (stereo pair with same display surface)

- **Head-mounted**
  - (eyepiece-objective and microdisplay)

- **Immersive**
  - (blocks direct-viewing of real world)

- **See-through**
  - (superimposes synthetic images onto real world)
Taxonomy of 3D Displays:

Spatial Multiplexing (e.g., Anaglyphs)

Glasses-bound
Stereoscopic

Head-mounted
(eypiece-objective and microdisplay)

Multiplexed
(stereo pair with same display surface)

Immersive
(blocks direct-viewing of real world)

See-through
(superimposes synthetic images onto real world)

Spatially-multiplexed (field-concurrent)
(color filters, polarizers, etc.)
Taxonomy of 3D Displays:

Temporal Multiplexing (e.g., Shutter Glasses)

- Head-mounted (eyepiece-objective and microdisplay)
- Multiplexed (stereo pair with same display surface)

Glasses-bound Stereoscopic

- Immersive (blocks direct-viewing of real world)
- See-through (superimposes synthetic images onto real world)
- Spatially-multiplexed (field-concurrent) (color filters, polarizers, autostereograms, etc.)
- Temporally-multiplexed (field-sequential) (LCD shutter glasses)
About EE 267

• experimental class, taught for the 2nd time (help us improve it!)

• lectures + assignments = one big project – build your own VR HMD

• all hardware provided, but must return at the end

• enrollment limited, because it’s a lab-based class and we only have limited hardware kits

• will be offered again (if students like the class)
About EE 267 - Goals

- understand fundamental concepts of VR and Computer Graphics
- implement software + hardware of a head mounted display
- learn basic WebGL/JavaScript and Arduino programming
- build your own HMD
About EE 267 – DIY HMD
About EE 267 – VRduino

- IMU
- Teensy 3.2
- 4 photodiodes
- other GPIO pins
About EE 267

- all important info here: http://stanford.edu/class/ee267/

- piazza: https://piazza.com/class/iyxrej40kso4af (see website)

- contact: ee267-spr1617-staff@lists.stanford.edu
About EE 267 - Prerequisites

• strong programming skills required (ideally JavaScript) do NOT take this course if you have not programmed!

• basic linear algebra required – we will start dreaming in 4x4 matrices

• introduction to computer graphics or vision helpful
About EE 267 – Lectures & Labs

- 2 lectures per week: Mo/Wed 3-4:20 pm, 380-380c

- 1 lab per week in Packard 001, every Friday (starting in week 1)

- labs - pick ONE time of: 9am, 11am, or 1pm

SIGN UP HERE:

https://docs.google.com/a/stanford.edu/spreadsheets/d/10tEwPrCnQqu9gQEpnRTJhcTe5xMc0X8WyGZ8mASwWwc/edit?usp=sharing
About EE 267 – Labs & Assignments

- lab every Friday in Packard 001 – attendance highly recommended!

- TA will help you get started, finish weekly assignment/project on your own

- 24h lab access will be provided after first lab (except for Fridays, during other labs)
About EE 267 – Lab Access

- review this website for lab policy: https://stanford.app.box.com/v/Basic-Lab-Safety

- to get ID access, email Steven Clark (EE teaching lab manager) your name & Sunet ID number (as well as an acknowledgement that you read the lab policy): steveclark@ee.stanford.edu
About EE 267 – Office Hours

• Gordon (instructor): Mondays 1:50-2:50pm, Packard 236 come talk about projects, VR, course logistics, etc.

• Keenan (TA): Tuesdays 3-4:30pm, Packard 001

• Hayato (TA): Wednesdays 4:30-6pm, Packard 001

• Robert (TA): Thursdays 4:30-6pm, Packard 001 come talk about labs, assignments, …
EE 267 – 3/4 unit version

Both versions:
- 7 assignments covering all aspects of VR tech

3 Unit version:
- 8th assignment (2 weeks)
- no report

4 Unit version:
- major final project – hardware, software, or perceptual experiments
- project report required (more details later)
Requirements and Grading

- 7 assignments (teams of ≤ 2): 70%

- 8th HW or major final project (teams of ≤ 2): 30%
  - discuss project ideas with TA & instructor!
  - final presentation / demos: Friday of dead week in Packard 001 during your lab
  - reports & code due: Thu in finals week, midnight
Course Projects

- June 9 (during your lab session): project poster + demo session
  - see poster template on website
  - celebrate your work and connect with students, faculty, and industry!
  - may invite many people from industry: Oculus, Google, Magic Leap, Intel, Nvidia, Olympus, Canon, …
Course Projects – ONLY for 4 unit version

- **June 12**: report + source code due (at midnight)

- report = conference paper format ~6 pages with
  - abstract
  - introduction
  - related work
  - theory / background
  - results
  - discussion and conclusion
  - references
  - see latex template on website (will be there)
Possible Course Projects

• be experimental!

• for example:
  • psycho-physical experiments (e.g. test stereo rendering with color/gray, low-res/high-res, …)
  • build an elaborate virtual environment, e.g. with unity
  • hardware projects: IMU, positional tracking, eye tracking, haptics, …
Tentative Schedule

http://stanford.edu/class/ee267/