CS294-137: Theory and Applications of Virtual Reality and Immersive Computing

Achin Bhowmik, James O'Brien, Allen Y. Yang

Fall, 2017

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Lecturers

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Chief Scientist, Avametric

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Other Guest Lecturers: CAC.berkeley

All | Localization | Imaging | Immersion | Interaction | Applications | Business | Arts+Design | Graphics

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Other Resources @ Berkeley

FUNG INSTITUTE FOR ENGINEERING LEADERSHIP
UC BERKELEY ENGINEERING

PROGRAMS CAPSTONE CAREER ALUMNI RESEARCH

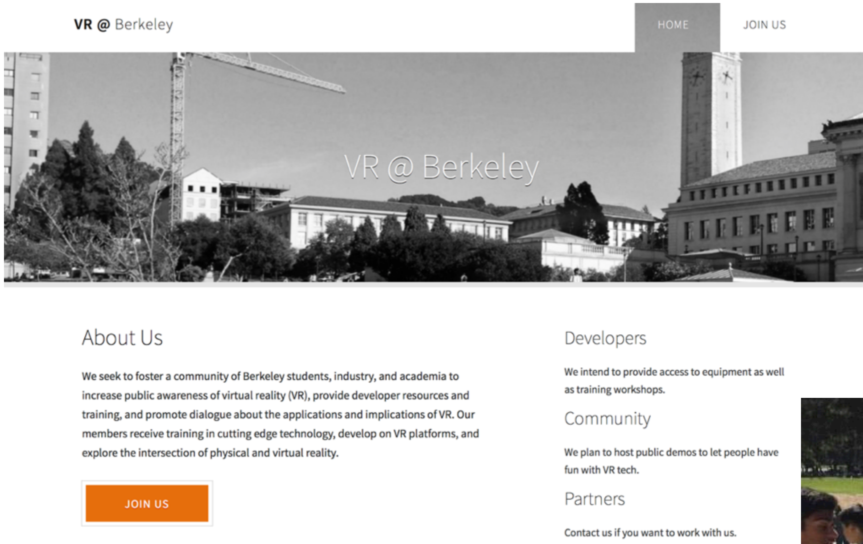
Master of Engineering Program

Teaching technical expertise and leadership

PROGRAMS

MASTER OF ENGINEERING PROGRAM

Other Resources @ Berkeley



- Founded in Spring 2015
- >200 members in each semester enrollment

VR@Berkeley

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Course Schedule

Week 1 (8-23): Introduction and Capstone Options
Week 2 (8-30): Human Perception in the Context of VR
Week 3 (9-6): Basic Unity3D/VR Programming Workshop
Week 4 (9-13): Course project proposal presentation
Week 5 (9-20): Computer Graphics related topics
Week 6 (9-27): 3D Vision related topics
Week 7 (10-4): Optics and Display technologies
Week 8 (10-11): Localization and Mapping
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Week 9: (10-18) VR Film Making (Richard Hernandez)
Week 10 (10-25): Gaming (Jack McCauley)
Week 11 (11-1): Telemedicine (Ruzena Bajcsy/Gregorij Korillo)
Week 12 (11-8): AR/VR in Arts & Design (Ted Selker)
Week 13 (11-15): Computational Imaging for VR (Ren Ng)
Week 14 (11-22): No class
Week 15 (11-29): Final project presentation
Week 16 (12-6): Final project presentation

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Grading Policy

Your final grades will be determined by four factors:

1. **Attendance by you (10%)**

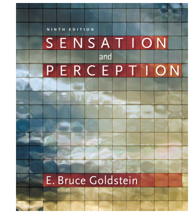
2. **Interaction during the class given by the lecturers (10%)**

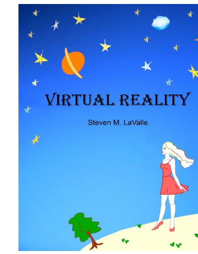
3. **Course/capstone project presentation (40%)**

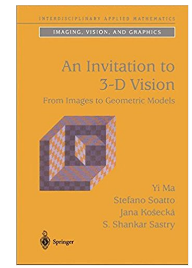
4. **A research paper discussing your project and its relevant literature and commercial applications (40%)**

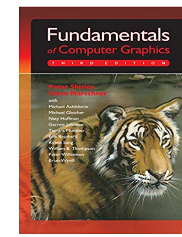
Recommended Reading Material

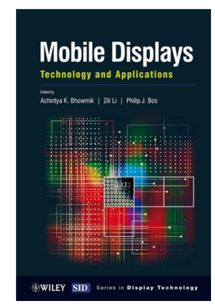
- **Perception:** Sensation and Perception
  by Bruce Goldstein
- **Virtual Reality:** Virtual Reality
  By Steven LaValle (and checkout his YouTube lectures)
- **Computer Graphics:** Fundamentals of CG
  by Peter Shirley
- **Computer Vision**: An Invitation to 3-D Vision
  by Yi Ma, et al.
- **Display: Mobile Displays**
  by Achin Bhowmik, et al.
- **AR/VR Market Research:** Virtual & Augmented Reality, understanding the race for the next computing platform
  by Goldman Sachs











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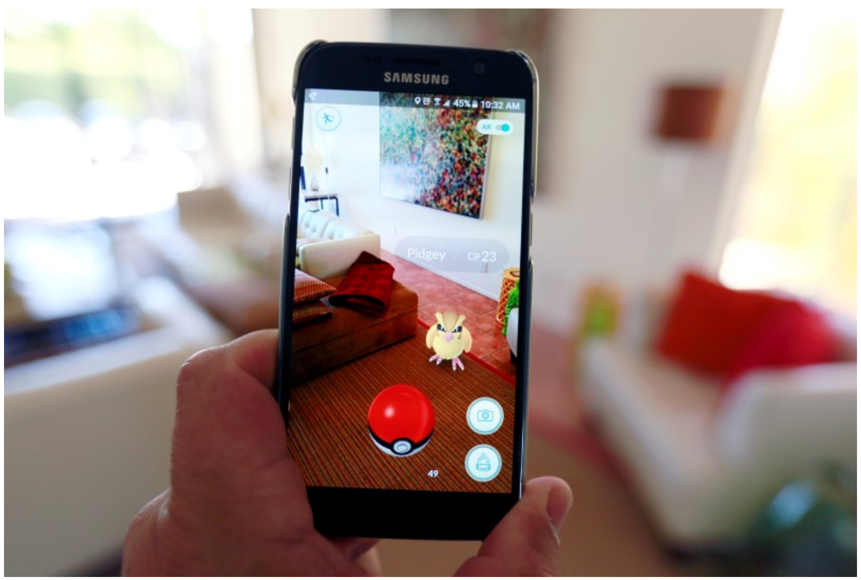
Goal of the Course

- Understand the fundamental theories that enable VR/AR and IC
- Understand the main technology drivers of VR/AR and IC markets
- Become an expert in criticizing the current software and hardware solutions
- Being about the invent new solutions that address existing needs / pain points of VR/AR and IC applications
- (Optional) Being motivated to pursue a career in relevant research or entrepreneurial fields

AR/VR: A Hot Market in 2016



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Holodeck: A VR Experience

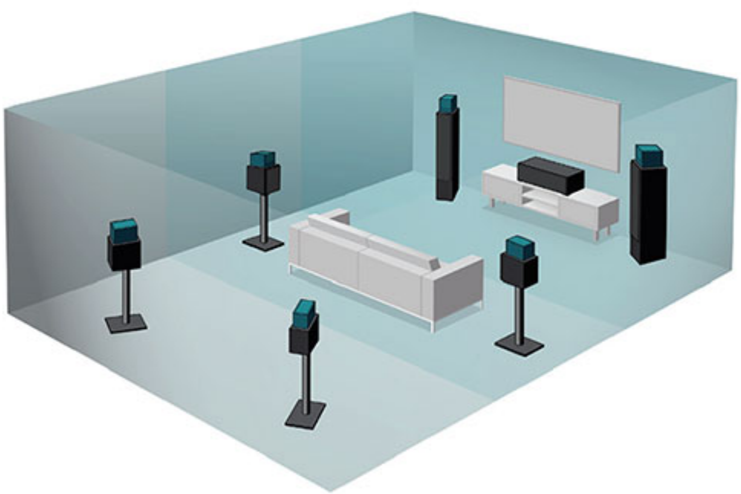
Leia’s Hologram: An AR Experience

Brief History of VR/AR/IC

Graphics

Photography

Stereoscopy



3D Audio

Interaction

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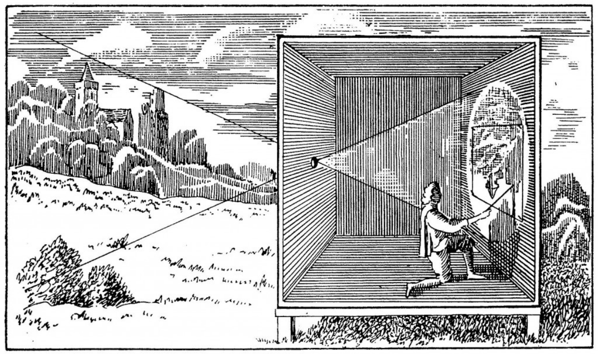
Early Forms of Paintings and Arts

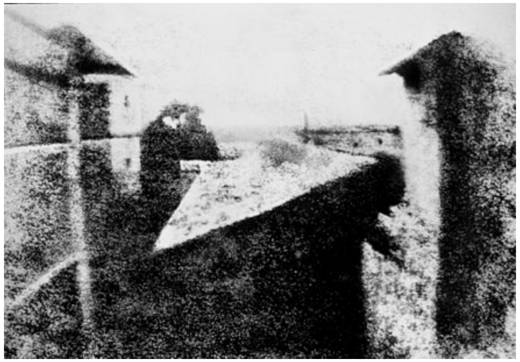
Cave paintings
Since 35,000 – 40,000 BP

Writing and languages,
Since 3100 BC

Early Forms of Photography



Camera Obscura, circa 400BC



First photo on paper, 1800s

Kodachrome, 1935

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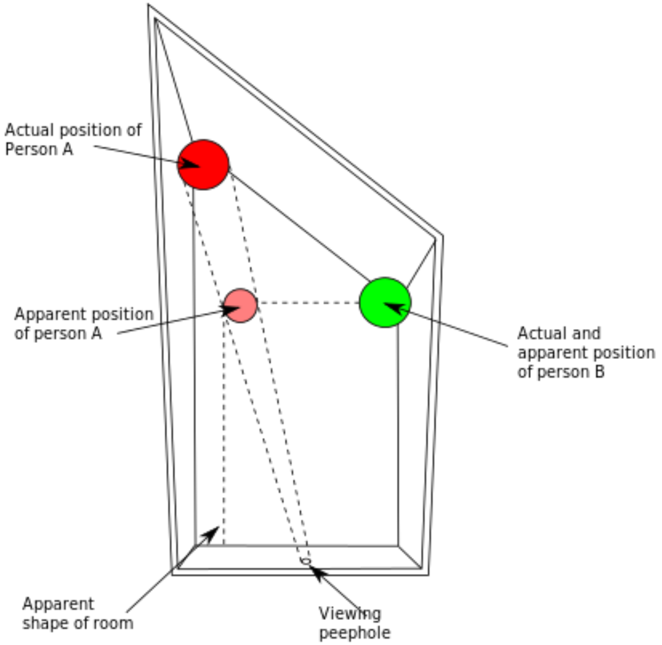
3D Illusion with Perspective



Ames Room, by Adelbert Ames, Jr., 1946

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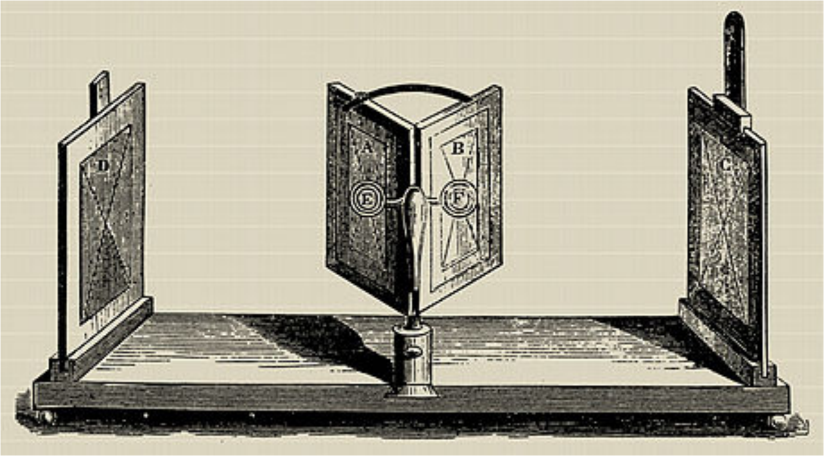
Seeing 3D from Stereo



Wheatstone mirror stereoscope, 1838

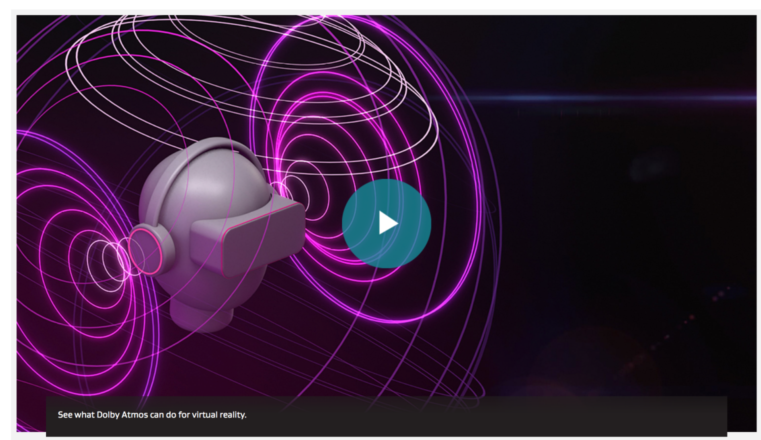
Holmes stereoscope, 1861

Audio: From Mono to Spatial 3D

Edison cylinder phonograph, 1899

Invention of headphones, 1910s

Dolby Stereo, 1977



Dolby Atmos for VR

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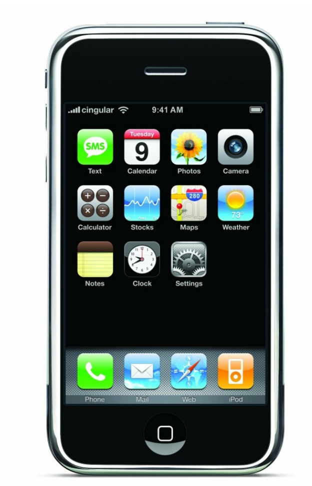
Interaction Modalities

Keyboard, since 1860s

Mouse, Douglas Engelbart, 1963



iPhone, 2007

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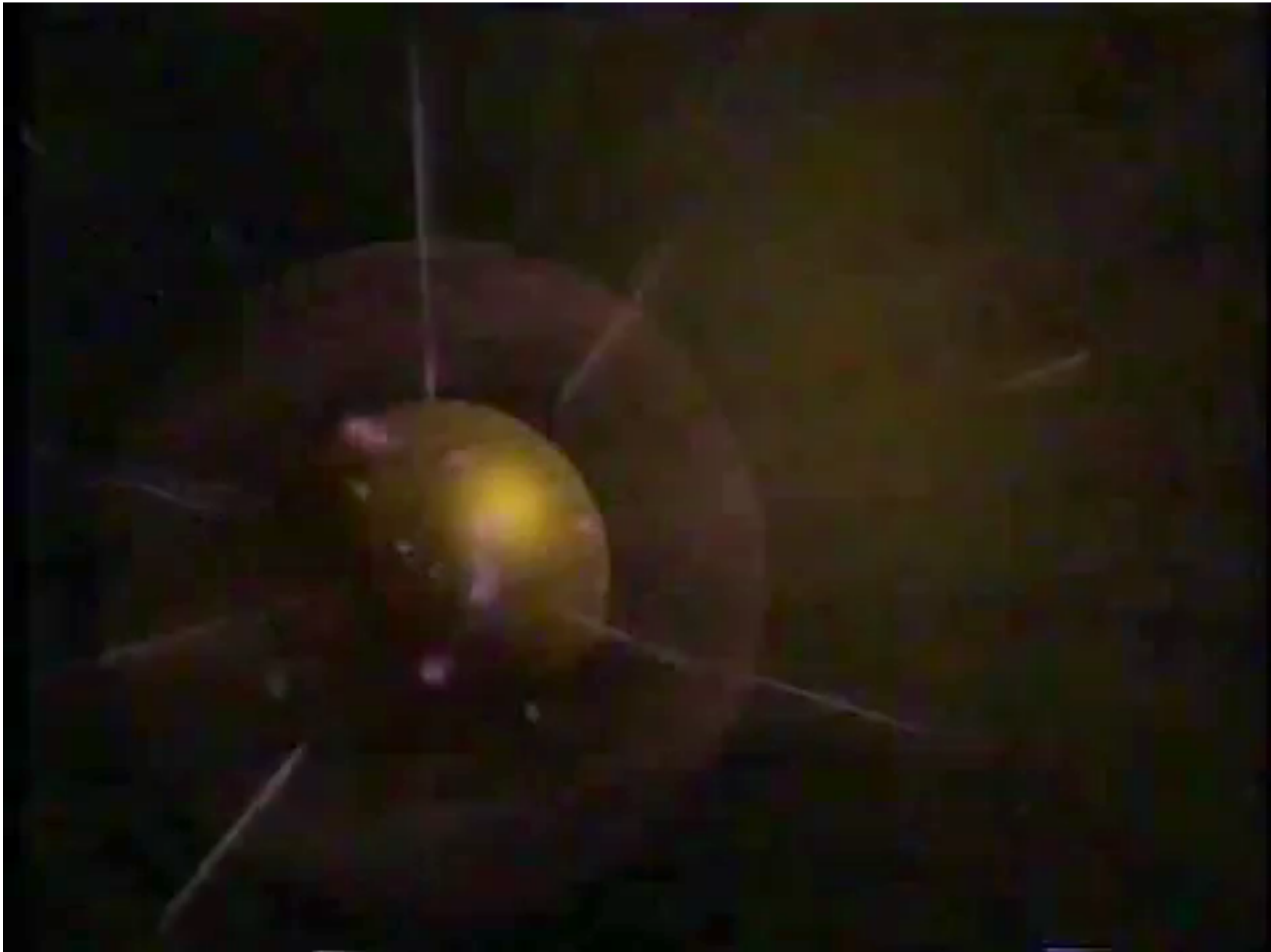
Hands as 3D Input Device

Sensorama: The First VR Prototype

Morton Heilig, 1958

Virtuality: Dawn of VR Gaming



Tilt Brush in Virtual 3D

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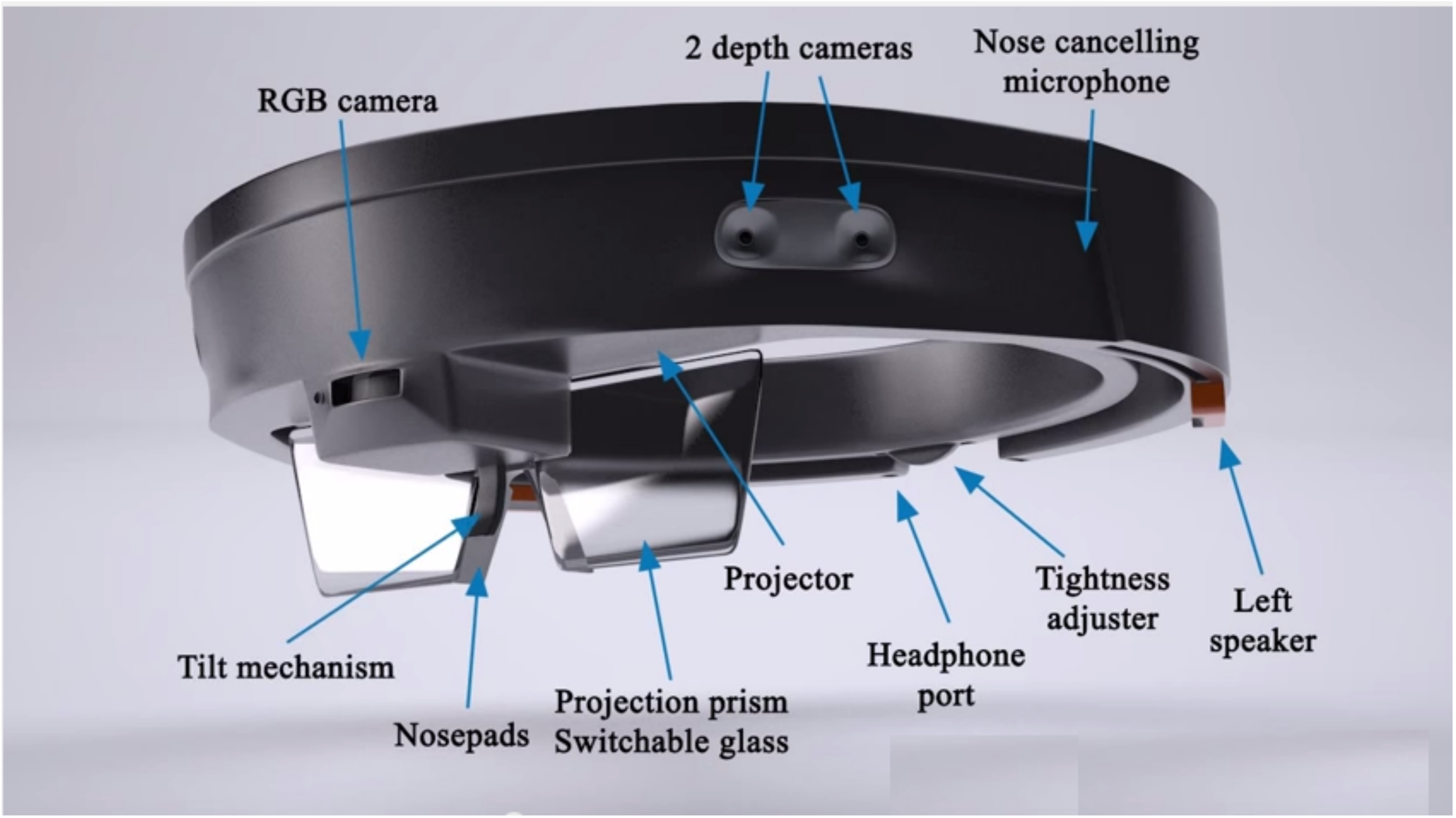
CES 2017: Samsung 4D VR Experience

The First AR Prototype

Anatomy of an AR Device: HoloLens



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Definition: Virtual Reality

- **VR** is a computer technology that uses head mounted displays, sometimes in combination with other sensory devices, to generate realistic images, sounds, and other sensations (touch, smell, motion, etc.) that simulate a user's physical presence in a virtual environment.

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Definition: Augmented Reality

- **AR** is a computer technology that augments a physical, real-world environment directly or through its indirect view computer-generated sensory information, including graphics, video, and sound. AR may alter a user’s view of reality, and may also enhance one’s perception of reality.

Enabling Technologies/ Open Research

- Near-Eye Displays and Optics
- 3D Localization
- 3D Content Capturing
- New Human-Computer Interface

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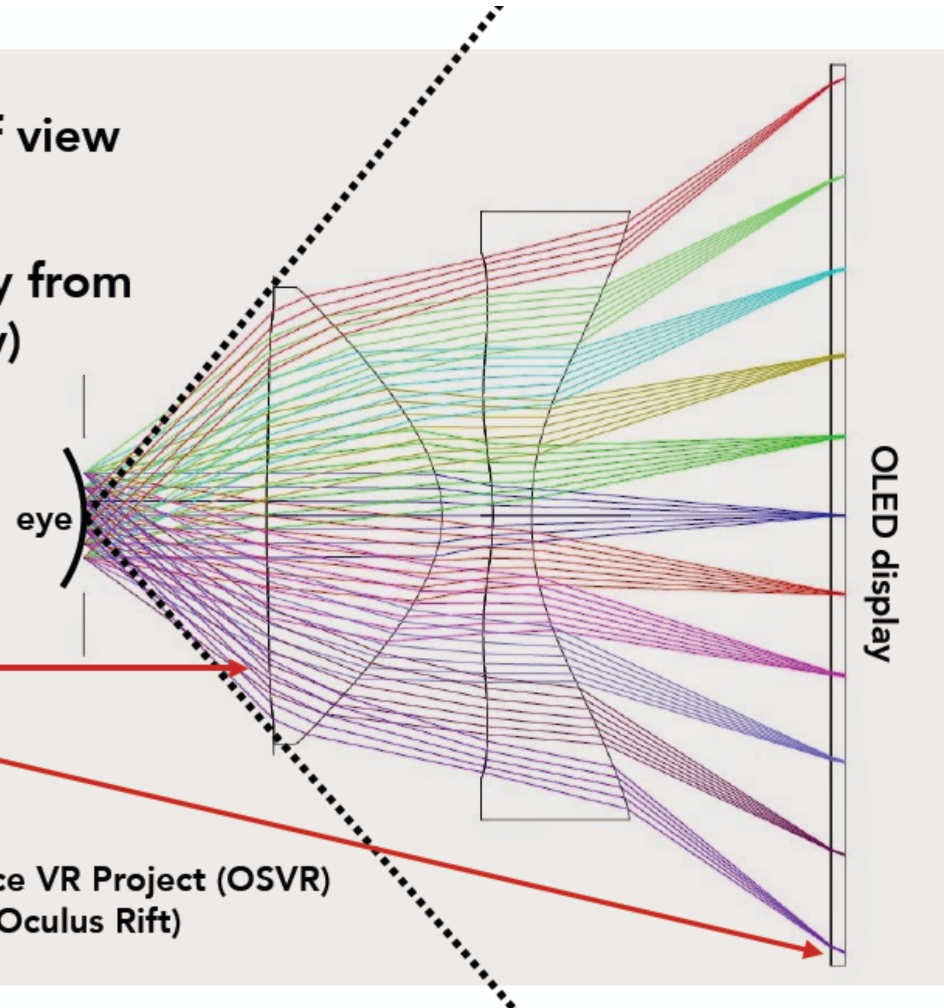
Near-Eye Optical Module

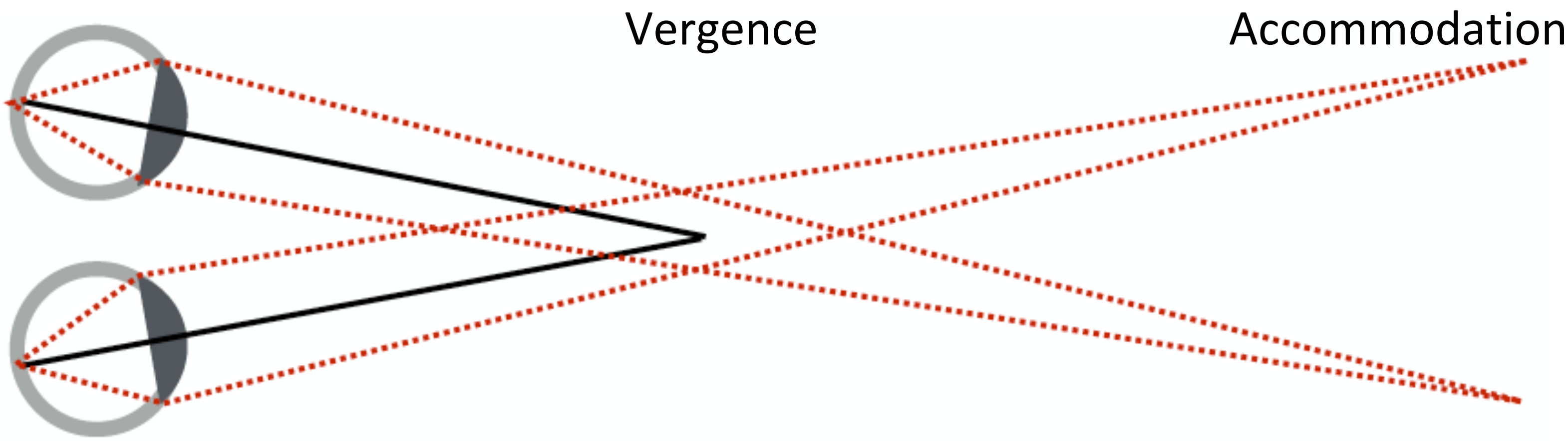
1. Create wide field of view
2. Place focal plane at several meters away from eye (close to infinity)



Note: parallel lines reaching eye converge to a single point on display (eye accommodates to plane near infinity)

Lens diagram from Open Source VR Project (OSVR)
(Not the lens system from the Oculus Rift)
http://www.osvr.org/

HMD Stereo Display Challenge



Localization via Beacons

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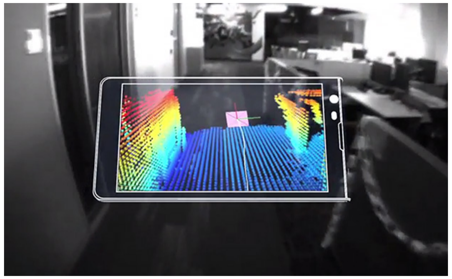
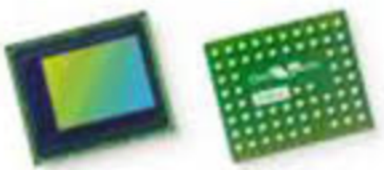
Localization via Depth Perception



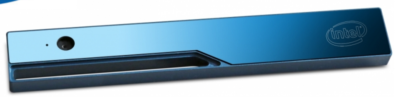
OmniVision

Microsoft



intel

SONY



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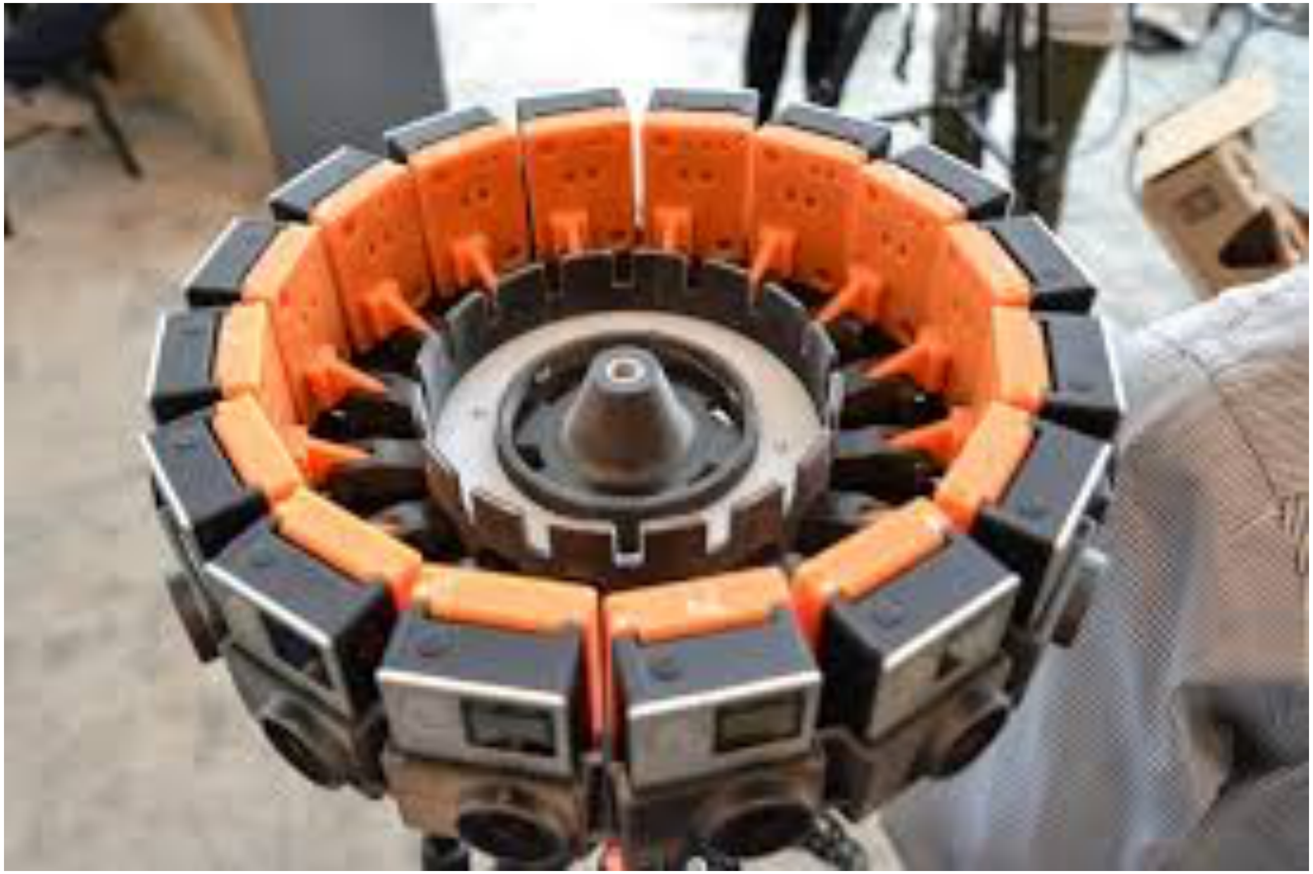
Google Tango Inside-Out Localization

360 VR Capturing: Photo Stitching



Google Jump VR

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From 360 VR to Real-Time 3D VR

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Lytro Immerge

New 3D Human-Computer Interface

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New 3D Human-Computer Interface

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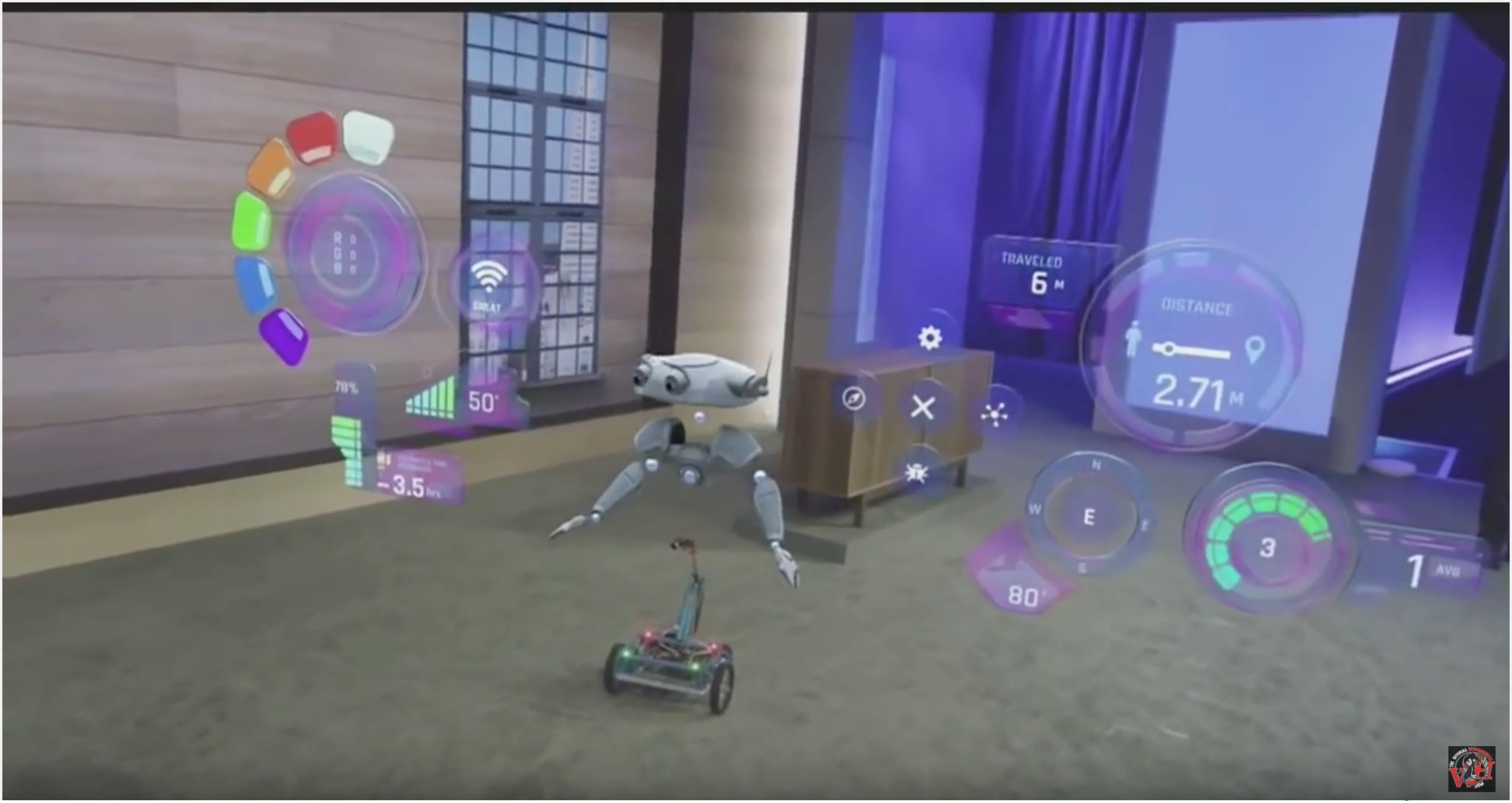
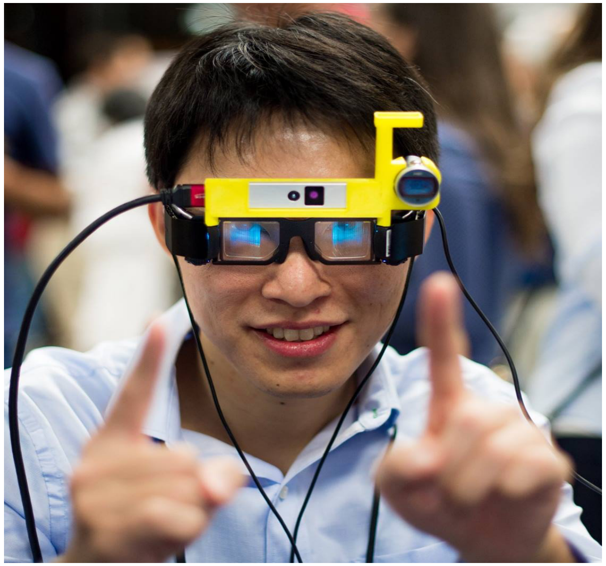
Connecting AR/VR and Robotics



Course/Capstone Projects Examples



Berkeley OpenARK

- Lumus
- PMD
- Webcam
- Motion Sensor
- Microsoft Surface Pro
- <$5K per unit

SIEMENS

HUAWEI

STATE GRID CORPORATION OF CHINA

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Beta released early 2017

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ISAACS: Immersive Semi-Autonomous Aerial Command System

SEEING IS BELIEVING

Leveling up with augmented reality

STORY BY DANIEL MCGLYNN • PHOTOS BY NOAH BERGER

When I was a kid, I would set off traversing orienteering courses through the hardwood forests of my native New England. The goal was to find a flag somewhere far off a trail using a topographic map and compass. It's a very interactive process: I was constantly positioning the map, readjusting headings and trying to find discernible landmarks.

Sometimes I would end up lost; other times, with my bearing right on, I felt like a successful explorer, emerging from the untrammeled wilderness. It was a straightforward lesson about how using technology, albeit simple, changed the way I considered what was right in front of me.

I haven't thought about orienteering in a long time. These days, my wayfinding needs are typically satisfied by opening Google Maps on my phone. But recently, as I sat down with electrical engineering and computer sciences (EECS) major Daniel Pok and computer science major Isabel Zhang, the cofounders of a relatively new student organization called VR@Berkeley, my mind wandered back to my experiences with maps and compasses.

We talked about how virtual reality (VR) and augmented reality (AR) — once relegated to movie screens and sci-fi novels — are poised to revolutionize computing. Forty years ago, we saw AR's potential in the opening scene of the "Star Wars" epic, when Luke Skywalker responds to a hologram of a distressed Princess Leia.

Today, if the recent Pokémon Go craze (where players blend the fictional world of Pokémon with real-world environments) is any indication, AR has arrived.

Through a combination of hardware and software, AR and VR convert computing from a flat two-dimensional screen to an immersive, interactive, three-dimensional experience. AR users wear a headset, but retain some visibility. Software is constantly mapping a user's surroundings with efficient localization functions and then simultaneously overlying digital images and interfaces in appropriate places in the real physical surroundings.

VR is a different experience: users wear an eye-covering headset, which serves as a wearable screen with embedded motion sensors — a fully synthetic digital experience that is completely divorced from actual physical surroundings.

Pokémon Go isn't quite AR because it uses a phone screen instead of a headset, so it's not completely immersive. The game does, however, give a glimpse of where the technology is heading.

So far, commercially available VR applications include gaming and entertainment. While a few limited AR products are available now, Silicon Valley-based consulting firm Digi-Capital predicts that the field will explode in market value, reaching $150 billion by 2020. Potential applications range from telemedicine to more intuitive control for robots on factory floors.

For Zhang, the technology is already life-changing. She was carrying heavy biology-related course loads with aspirations of pursuing a career in medicine when Pok introduced her to VR. "I got interested in VR and then took an intro computer science course. After that, I decided to switch to computer science," Zhang says. "So it's definitely changed my life." Now she's creating immersive animated short films. "Watching a film in VR can create so much more emotion and evoke a lot more out of a wide variety of people. Being able to contribute to that is exciting."

The VR club started with a handful of members in early 2015, and has since grown to 200 members from across campus working on a range of projects, including making an augmented 3-D virus model that pops off the page of a biology textbook and how to use virtual reality to play the Campanile's carillon.

"The idea is that VR is the ultimate medium," Pok says. "When you get there, you can shape the world however you want."

Pok, Zhang and fellow members of Berkeley's VR club are advised by Allen Yang, executive director of the Center for Augmented Cognition (CAC), headquartered in Cory Hall. Yang is working at a new frontier, one where the topography of the physical world is being reconfigured by digital tools.

Yang came to Berkeley as an EECS postdoctoral researcher in 2006. After a stint in industry as employee number one at Atheer Labs, the maker of headsets that enable interactive computing, he returned to campus to lead CAC, along with faculty director Shankar Sastry, also dean of the college. The center opened this spring, after the college identified the need to integrate emerging research on virtual and augmented reality, including human-computer and human-robot interactions.

"We realized we need two things," Yang says about the center's founding. "We need resources for researchers and students to be able to conduct projects or research in this area, and we need to have a community that can circle around this topic."

Unlike many other university-based research areas, where commercial products follow theoretical research,

Drone Fleet Control (Tomlin)

Drone Safety Control (Tomlin)

VR in Autonomous Driving (Borrelli)

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