# 虛擬實境
# VR Craze and Four Major Technical Problems to Solve in VR/AR: with an example application

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# Outline

1. VR/AR is just going through a **Cambrian explosion**

2. Four Major Problems to Solve in VR and AR

3. An example application:

Scope+ : A Stereoscopic Video See-Through Augmented Reality Microscope

# Definition of Virtual Reality and Augmented Reality

- Virtual Reality:

**Virtual reality** (**virtual realities VR**) typically refers to computer technologies that use software to generate realistic images, sounds and other sensations that replicate a real environment (or create an imaginary setting).

- Augmented Reality:

**Augmented reality** (**AR**) is a live direct or indirect view of a physical, real-world environment whose elements are *augmented* (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPSdata.

It seems that VR/AR is just going through the **Cambrian explosion!**

- Google glass (product cancelled)
- Oculus Rift/Rift 2 (purchased by Facebook, 2 billion US$)
- Google Cardboard VR project
- Magic Leap secures 542M by Google Inc.
- Microsoft HoloLens project

all these happened in 2014/2015!

# 2016: The Year of Virtual Reality ?

**2016: the year when VR goes from virtual to reality**

2017 as the *real* year of virtual reality: as declared by industry

# Four major problems in VR/AR

1. Display  resolution: wide angle display, without seeing pixels in display

2.Latency: should be less than 20 to 50ms

If greater than 50 to 100 ms, will cause dizziness, even nausea.

3.fixed focus vs. variable focus in observation through HMD or others.

4.Registration of real objects and virtual environments in AR

# Extremely cheap HMD: US$6-20

# Half a million sold in one week!

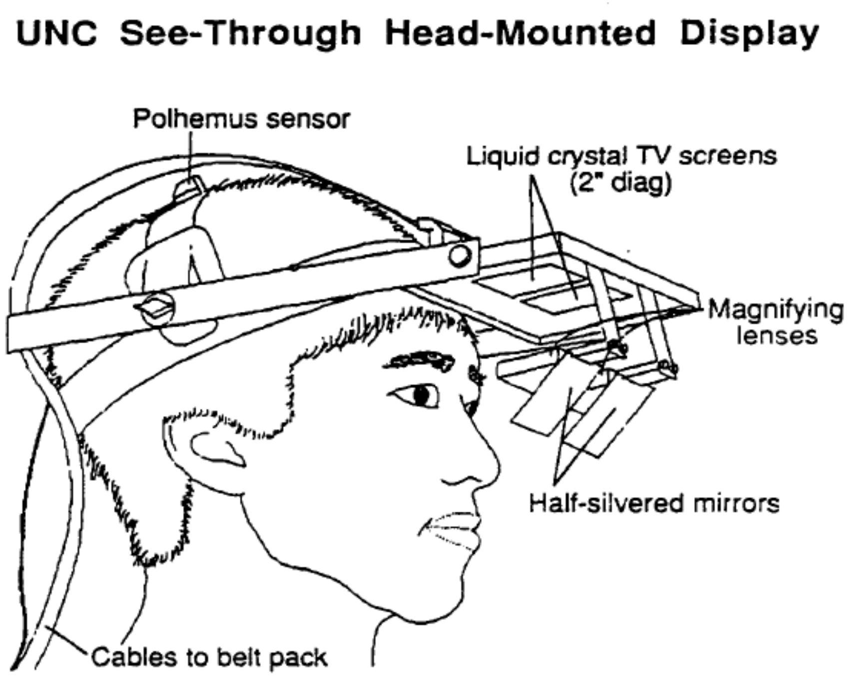
(December 16, 2014 news)

- Less than a week after going on sale and dropping rather quietly on an unsuspecting America, Project Cardboard has rocketed past the 500,000 sales mark. Such is the popularity of the DIY virtual reality toy that Google has even built and launched a dedicated area of the Play Store for apps created for or ideally suited for use with the unusual piece of facewear.

# Why so popular?

- “The growth of mobile, and the acceleration of open platforms like Android make it an especially exciting time for VR,” beamed Andrew Nartker, project manager for Google Cardboard.

# 30 years from UNC HMD: much cheaper! (Display, Sensors)(Ref: paper in 1989!)




Polhemus position/orientation sensor: US$2000, 25 years ago.
Display: LCD TV screens: US$400 per set, and need 2 of them!

# Polhemus trackers

- Polhemus pioneered the original AC electromagnetic head tracking in the late 1960's and has advanced the technology in tracking excellence ever since.
- full six-degrees-of-freedom (6DOF) motion tracking

# Android Apps

*For HTC, Samsung, Xiaomi  Inc.  etc.: best VR Apps,*

- *1. Rollercoaster VR*
- *2. Cardboard VR app*
- *3. Cosmic Rollercoaster VR app*
- *4. Jurassic Dino VR*
- *5. Crazy Swing VR*
- *6. Space Terror (need Bluetooth controller to play)*

# 3D Video from Youtube

Key word: “3D” or “3D trailers” “360 vr” for 3D glasses

Example titles:

Air Racers, real airplane stunt show

Samsung 3D demo

Avatar 3D

WoW, World of Warcraft

Finding Nimos, is one good example,

NYT vrse,

# Google Street View (VR mode)

- Lower falls of the Yellowstone,
  Old Faithful, Yellowstone
  Musee d'Orsay, Paris
  Musee du Lourve, Paris,
  Niagara falls, On, Canada, (Google, on boat move forward)
  Himalayas (ABC， Annapurna Base Camp， by Jonathan Jenkins, clear view of Everest
  Avila Spain (City walls, ancient one）
  Segovia Spain, Sevilla, Spain
  Toledo, Spain

# More choices: Gear VR by Oculus (US$199.), and from HTC!

# Spec.

## 96° Field of View

Sensor:

Accelerator, Gyrometer, Geomagnetic, Proximity

Motion to Photon Latency: < 20ms

Focal Adjustment:

Covers Nearsighted / Farsighted Eyes

Interpupillary Distance Coverage

55 ~ 71 mm

# Gear VR with Samsung Galaxy Note 4

Display:

- 5.7 inch (143.9mm) Quad HD Super AMOLED (2560×1440)

Physical User Interface

- Touch Pad, Back Button, Volume Key

Audio:

- 3D Spatial Sound on Samsung VR Player for VR Gallery contents (Earphone needed)

# Google Daydream View VR

# Daydream View VR FOV: 90 degrees

- For Pixel, you're looking at 1080 x 1920 pixels, 5 inch AMOLED (441ppi) and while the XL is 1440 x 2560 pixels, 5.5 inch AMOLED display (534ppi).
- There are only five buttons including a trackpad that doubles as a button. Below the trackpad, you'll find an app button, which can show menus, pause, go back or change modes depending on the app itself.
- When you look at the screen in your VR headset, you will often see a regular grid of lines.

# HTC VIVE HMD

- Vive has a refresh rate of 90Hz,
- two screens, one per eye, having a total resolution of 2160x1200 (1080 x 1200 per eye)
- uses more than 70 sensors including a MEMS gyroscope, accelerometer and laser position sensors, and is said to operate in a 15 feet by 15 feet (4.5 by 4.5 meters) tracking space if used with a passive "Lighthouse" base station (x2)

# Oculus Rift 2 vs. HTC Vive


| | **Oculus Rift** | **HTC Vive** |
|---|---|---|
| Display | OLED | OLED |
| Resolution | 2160 x 1200 | 2160 x 1200 |
| Refresh Rate | 90Hz | 90Hz |
| Platform | Oculus Home | SteamVR |
| Field of view | 110 degrees | 110 degrees |
| Tracking area | 5x11 feet | 15 x 15 feet |
| Built-in audio | Yes | Promised, not yet available |
| Built-in mic | Yes | TBA |
| Controller | Oculus Touch, Xbox One controller | SteamVR controller, any PC compatible gamepad |
| Sensors | Accelerometer, gyroscope, magnetometer, 360-degree positional tracking | Accelerometer, gyroscope, laser position sensor, front-facing camera |

# Need very powerful GPU for display, and that powerful PC can be very expensive!

- HTC VIVE: NVIDIA GeForce GTX 970 /AMD Radeon RX 480 equivalent or greater

- Occulus Rift 2: NVIDIA GeForce GTX 960 / AMD Radeon RX 470 or greater

- Because the FOV is 110 degrees, we can easily see pixel grid in the display (The display resolution of 2160 x 1200 is NOT enough for 110 degrees field-of-view. 10K by 10K is the optimal solution in the future)

# HTC VIVE focus (2018/2)

Qualcom 835 chip set
Resolution: 2,880×1,600
WiFi: WiGig
NT 18,500

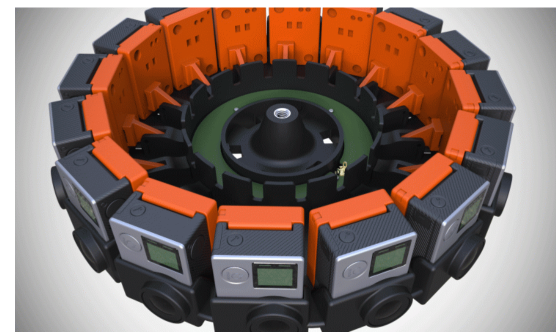
# App: Hot Air Balloon!

# 360 degree imaging devices

- 1. Ladybug 5 spherical camera:
  (five cameras)
- 2. Luna 360 camera
  (two fisheye cameras)
- 3. Google Jump VR Project (16 cameras)
- 4. Facebook surround 360 video camera
  (with 17 cameras)
- 5. Polycamera 360 imaging
  (with 4 fish eye camera)

1

2



3

4

5

# 360 imaging with stereo

360 imaging but without stereoscopic capture:

Ladybug 5 spherical camera, Luna 360 camera

360 imaging with stereo:

Google Jump VR Project, Facebook surround 360 video camera,

Polycamera 360 imaging

# Luna 360 camera: initial evaluation 2018/2

- The app connects to iPhone WiFi well
- Overall image quality is reasonably good, but not HD.
- Video quality is about the same, but audio seems to be poor. I could only hear muffled sounds.
- For images that are converted to panoramas, the stitching of the two images together is poorly done. Offsets and image scenes are very apparent.
- Both Pic and Vid are at 1920x1080. It's supposed to be 2 x 1080p camera but actually it's 960x960 x 2 lenses written into one 1920x1080 file.

One of the best apps in AR in the future, if combined with machine learning, (Even in Taiwan, we have 26 sets!)

- [DaVinci surgery machine]

# Four major problems in VR/AR

1. Display resolution: wide angle display, without seeing pixels in display

2.Latency: should be less than 20 to 50ms

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3.fixed focus vs. variable focus in observation through HMD or other display.

4.Registration of real and virtual objects in AR

# Problem 2: Latency (Compensation)

References


- Azuma R, Bishop G (1994) Improving static and dynamic registration in an optical see-through HMD. SIGGRAPH’94 Conference Proceedings,
- Jiann-Rong Wu and Ming Ouhyoung, "On Latency Compensation and its Effects for Head Motion Trajectories in Virtual Environments," *The Visual Computer*, vol. 16, no. 2, pp. 79—90, 2000.
- Jiann-Rong Wu and Ming Ouhyoung, "A 3D Tracking Experiment on Latency and Its Compensation Methods in Virtual Environments", Proc. of UIST'95 (User Interface and Software Technology 1995), pp. 41-49, ACM Press Pittsburgh, USA

- One of the critical problems is the perceived latency, or lag. This is the time delay from the user's input action until the response becomes available for display.

- The illusion of a virtual world is destroyed if the objects on the screen jitter significantly while the head is not in motion – the "swimming effect"

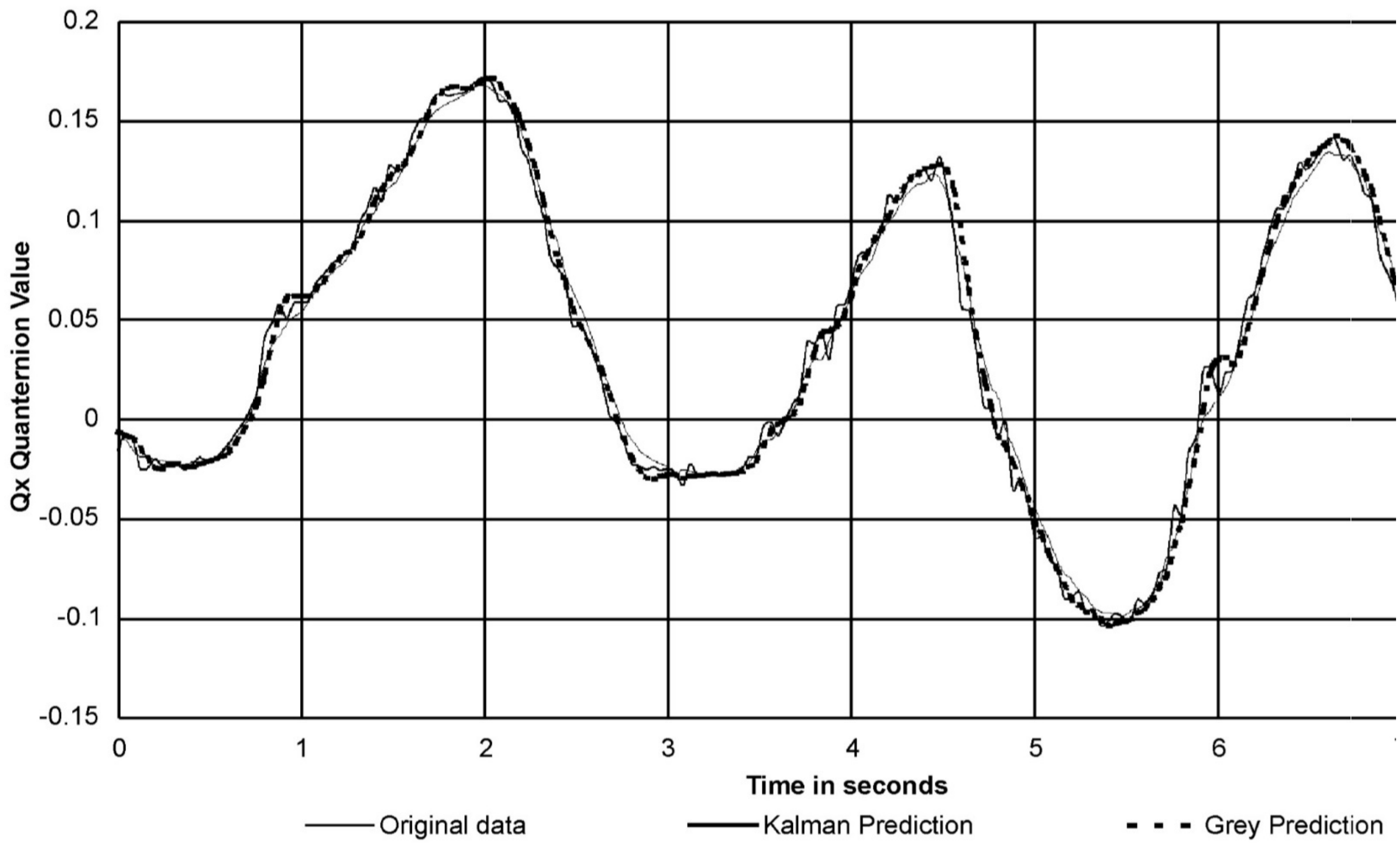
- Major components of end-to-end latency include (1) the time for internal processing by input sensors,(2) data transfer from the sensors to the host computer, (3) update of the physical simulation output by applications in response to user input, and (4) image rendering and display.

- System latency is the largest single source of registration error in existing AR systems, outweighing all others combined. Latency of ten results in virtual imagery lagging behind or “swimming” around the intended position.

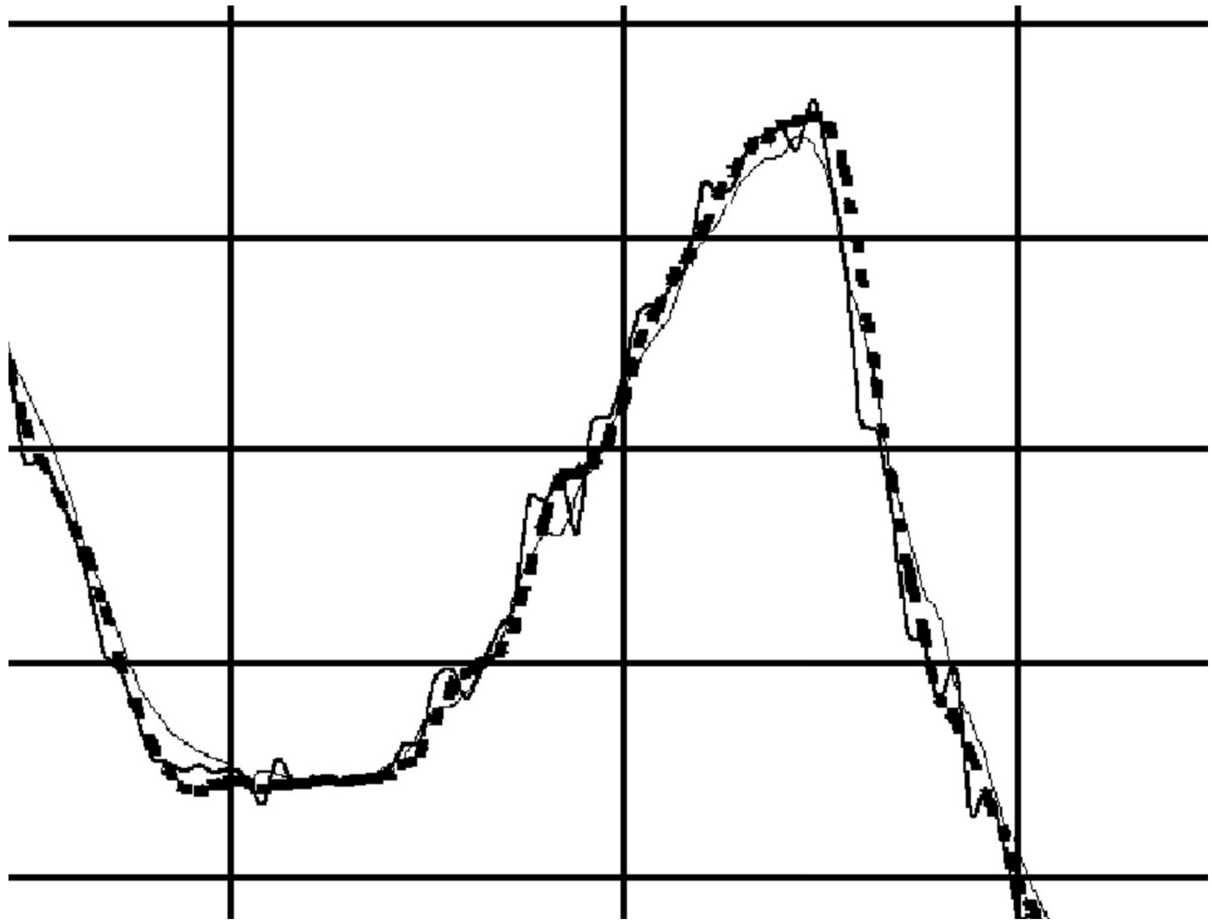
- Azuma and Bishop [1] used Kalman filtering with inertial sensors mounted on a see-through HMD to improve the dynamic registration, that is, to reduce the latency.
- The result can significantly aid the head-motion prediction in real cases; on the average, prediction with inertial sensors produces two to three times less errors than that of prediction without inertial sensors, and five to ten times less than that of using no prediction at all.

- However, at bigger latency (more than 130 ms), the prediction accuracy, with or without the use of inertial sensor in Kalman filtering, is not significantly different

# Plot of quaternion curve Qx (quaternion) with Kalman prediction without inertial sensor versus grey system prediction



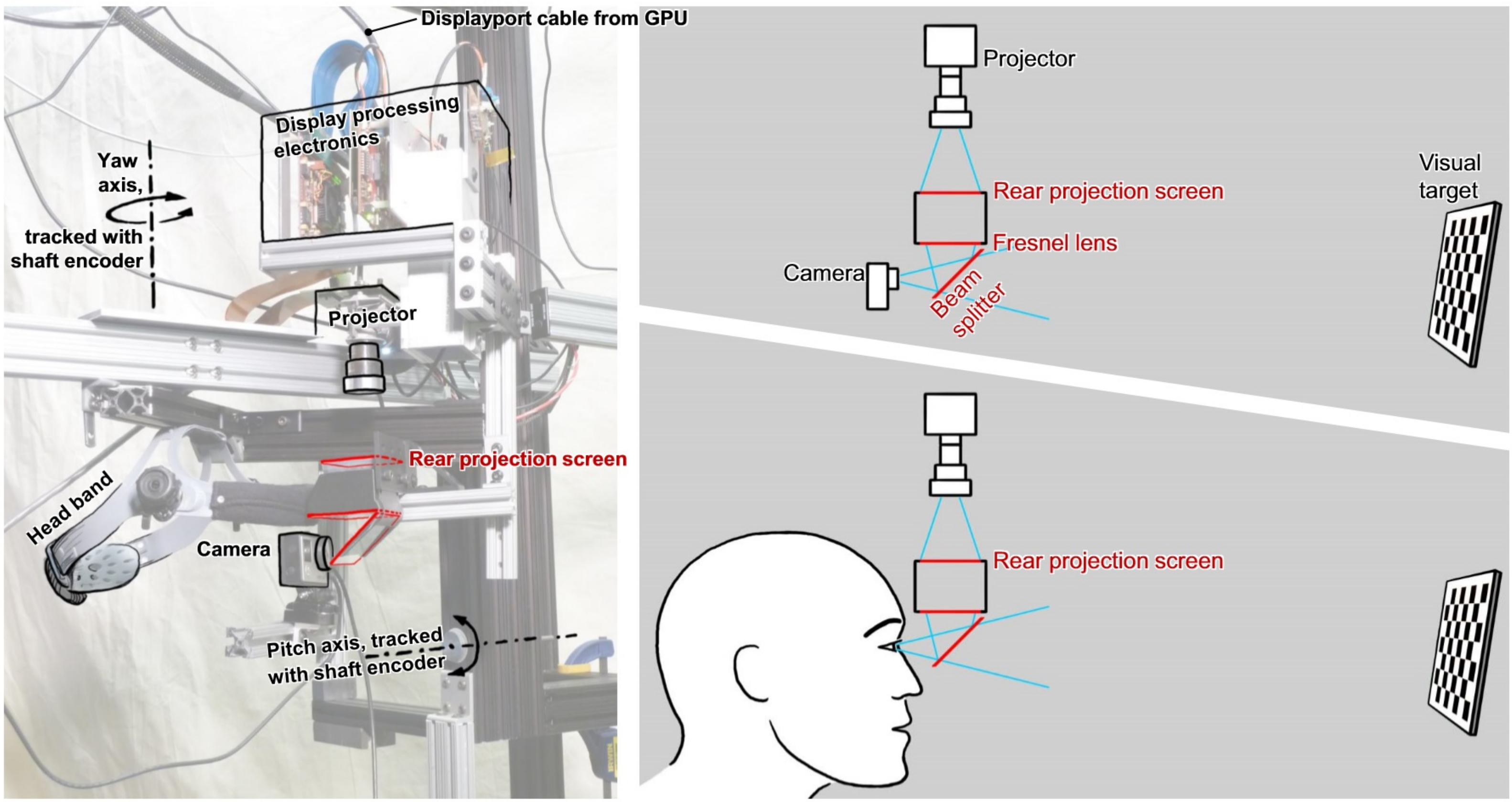
# Motion curve with latency compensation: Blow up figure



- From Motion to Photons in 80 Microseconds: Towards Minimal Latency for Virtual and Augmented Reality, 2015 IEEE Trans. On Visulization & CG

by Peter Lincoln, Alex Blate, Montek Singh, Turner Whitted, Andrei State, Anselmo Lastra, and Henry Fuchs

# How to measure latency?



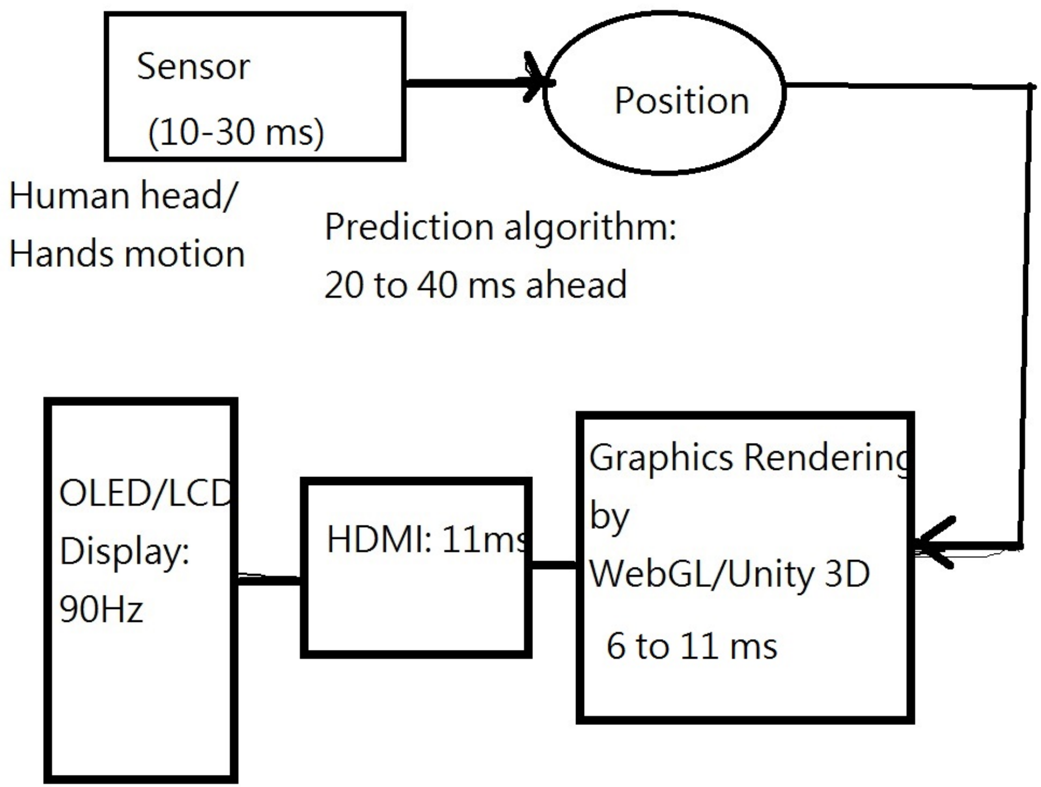
# A simple method: video demo

Show the output from LCD/OLED panel against the tracker motion

Latency measurement video

# Reducing the latency: Prediction (by Kalmann Filter, for example, for 20-40 ms prediction of head/hand motion)

- Occulus as well as HTC Vive




Why prediction of motion is needed?

# Latency in a typical very old VR system in early 90s

- the update rate can reach 15–20 frames/s on an SGI Indigo2 Extreme graphics workstation. Even though the update rate is enough to work with, it still has an overall latency of about 300 ms. The tracker contributes approximately 70 ms; the rendering pipeline, 80 ms; and the LCDs with relatively low refresh rates in the HMD contributes 150 ms.

# Measuring Motion-to-Photon Latency of Virtual Reality in Mobile Devices

Table of motion to photons latency for smartphones: unit in ms (the smaller the better)

| FAB (Processing Technology nm) | smartphones | PsViewer App | Google Street View (VR App) |
|---|---|---|---|
| 14nm/Adreno | Google Pixel | 60.4 | 50 |
| 16nm/PowerVR | iPhone 6s | 58.3 | 58.3 |
| 16nm/Mali | Redmi Pro | 58.3 | 58.3 |
| 14nm/Adreno | Sony XZ | 100 | 97.9 |
| 16nm/Mali | Huawei Mate 8 | 83.33 | 68.75 |
| 10nm/PowerVR | Meizhu Pro 7 plus | 45.8 | 41.7 |
| 10nm/AppleGPU | iPhone X | -- | 41.7 |

# Motion Sickness (VR Sickness)

1. Around 25 to 40 percent of people suffer from motion sickness depending on the mode of transport, scientists have estimated, and more women are susceptible than men. For example, 78% of women **got sick** playing a VR horror game , while 33% of men got sick playing the game.
2. In some ways, the very premise of virtual reality makes it an ideal vehicle for motion sickness– by Steven Rauch, director of the Vestibular Division at Massachusetts Eye and Ear in Boston.
3. Motion sickness has probably been with us as long as we’ve had boats. J.A. Irwin introduced the term motion sickness in the scientific literature in 1881.
4. The most widely accepted theory to emerge is that motion sickness is brought on by a mismatch between two or more of the senses that help you keep your balance.

# How to measure motion sickness?

## 1. Galvanic Skin Response (GSR, 皮膚電導反應)

**Electrodermal activity** (**EDA**), is the property of the human body that causes continuous variation in the electrical characteristics of the skin. Historically, EDA has also been known as **skin conductance**, **galvanic skin response** (**GSR**).

## 2. Simulator Sickness Questionnaire (SSQ) feedback

Simulator Sickness Questionnaire was developed by Kennedy and his colleagues in 1993 (Kennedy et al., 1993). They used over 1000 sets of previous data and through some analysis, they came up with a list of 27 symptoms which are commonly experienced by users of virtual reality systems. Each item is rated with the scale from none, slight, moderate to severe.

# Simulator Sickness Questionnaire: symptoms

| Symptoms | Weights for Symptoms | | |
|---|---|---|---|
| | Nausea | Oculomotor | Disorientation |
| General discomfort | 1 | 1 | |
| Fatigue | | 1 | |
| Headache | | 1 | |
| Eye strain | | 1 | |
| Difficulty focusing | | 1 | 1 |
| Increased salivation | 1 | | |
| Sweating | 1 | | |
| Nausea | 1 | | 1 |
| Difficulty concentrating | 1 | 1 | |
| Fullness of head | | | 1 |
| Blurred vision | | 1 | 1 |
| Dizzy (eyes open) | | | 1 |
| Dizzy (eyes closed) | | | 1 |
| Vertigo | | | 1 |
| Stomach awareness | 1 | | |
| Burping | 1 | | |

# Motion Sickness 2

Your eyes see that you are moving through the virtual world — in a virtual car or a virtual spaceship, or strolling down a virtual path — but your vestibular system knows you're not actually moving. “cue conflict”.

It's not clear why women would have better visual acuity for 3-D motion, but the results suggest that the more sensitive you are to sensory cues, the more likely you are to detect a mismatch.

In 1957, “flight simulators were making some pilots motion sick”, the U.S. military was the first to report .

# Motion Sickness 3

- One of the biggest tech hurdles for VR has been the inherent delay between when you move your head and when the display updates to reflect that movement. If the lag is too great, you can end up with a potentially vomit-inducing sensory mismatch.

- To avoid motion sickness: (1) as long as a step in the real world results in an equivalent step in the virtual world, moving around is fine too. But to explore further, you'll need to use handheld controllers with buttons, triggers and directional touch pads to move your virtual self around, and that's where things can go wrong.

(2) One of the most successful strategies developers have hit on is using teleportation to take short skips around the virtual world.

# Motion Sickness 4

- Basically you aim the controller where you want to go and the screen fades to black for a split second, sort of like the blink of an eye. When it fades back in, you're at the new location.

- (3) Self-reported ratings (warnings) for motion sickness: Those assessments might help people like me avoid the most nauseating games.

Oculus seems to have accepted that VR sickness can't be eliminated from all VR experiences at the moment, so most Oculus-approved games come with "comfort ratings" to let users know if a game or experience is more or less likely to make them sick.

# Motion Sickness 5: Guidelines to avoid motion sickness

- **Taking traditional motion sickness remedies:** ginger, Dramamine and scopolamine
- **Wearing a nerve-stimulating wristband**
- **Galvanic vestibular stimulation:** Applying electrical currents behind the ear to fool your vestibular system into thinking you're moving
- **Inserting a virtual nose into the field of view (**tested in a roller coaster game)
- **Adding a virtual cockpit to your experience**
- **Reducing the field of view during motion**
- **Expanding the field of view: (**Peripheral LEDs in the headset add light to make the view more realistic )
- **Using optical illusions:** The aim is to trick you into thinking you've covered more ground than you have, eliminating the need for controller-based movements
- **Walking on a specialized treadmill:** Lets you move in any direction while playing
- **Toughing it out until you develop your "VR legs"** (similar to sea legs)

# More on motion sickness: Part 6

**1. Nauseogenicity of off-vertical axis rotation vs. equivalent visual motion.**

Off-vertical axis rotation (OVAR) provokes motion sickness. The visual motion equivalent to OVAR in simulators is also nauseogenic.

**2. Off-vertical axis rotation of the visual field and nauseogenicity.**

Nauseogenicity of visual OVAR peaks around 0.2 Hz, and increases with stimulus strength up to circa 45 degrees tilt, similar to real motion.

3.

# Motion Sickness 7

The effects of people with Multiple Sclerosis (多發性硬化症, 神經傳導變慢) : However, participants with MS had significantly lower GSR during VR exposure. We compare the effects of cybersickness between the people with MS and the people without MS with respect to SSQ score and GSR data.

Avoidance by Machine Learning

"Towards a Machine-learning Approach for Sickness Prediction in 360 Stereoscopic Videos": we train a machine learning algorithm on hand-crafted features (quantifying speed, direction, and depth as functions of time) from each video, learning the contributions of these various features to the sickness ratings. IEEE VR 2018

# How to verify if VR/AR is useful? (How Real?)

- Fred Brooks, ACM Siggraph 2002

  Observation: Skin conductance, respiration, heart beat rate.

Meehan, M., B. Insko, M.C. Whitton, F.P. Brooks Jr., 2002: "Physiological Measures of Presence in Stressful Virtual Environments," *ACM Transactions on Graphics*, **21**, 3: 645-652. (*Proc. of ACM SIGGRAPH 2002*, San Antonio, TX).

- We hypothesized that to the degree that a VE seems real, it would evoke physiological responses similar to those evoked by the corresponding real environment, and that greater presence would evoke a greater response.

# Set up: with a ledge  (a board), 1.5 inch thick

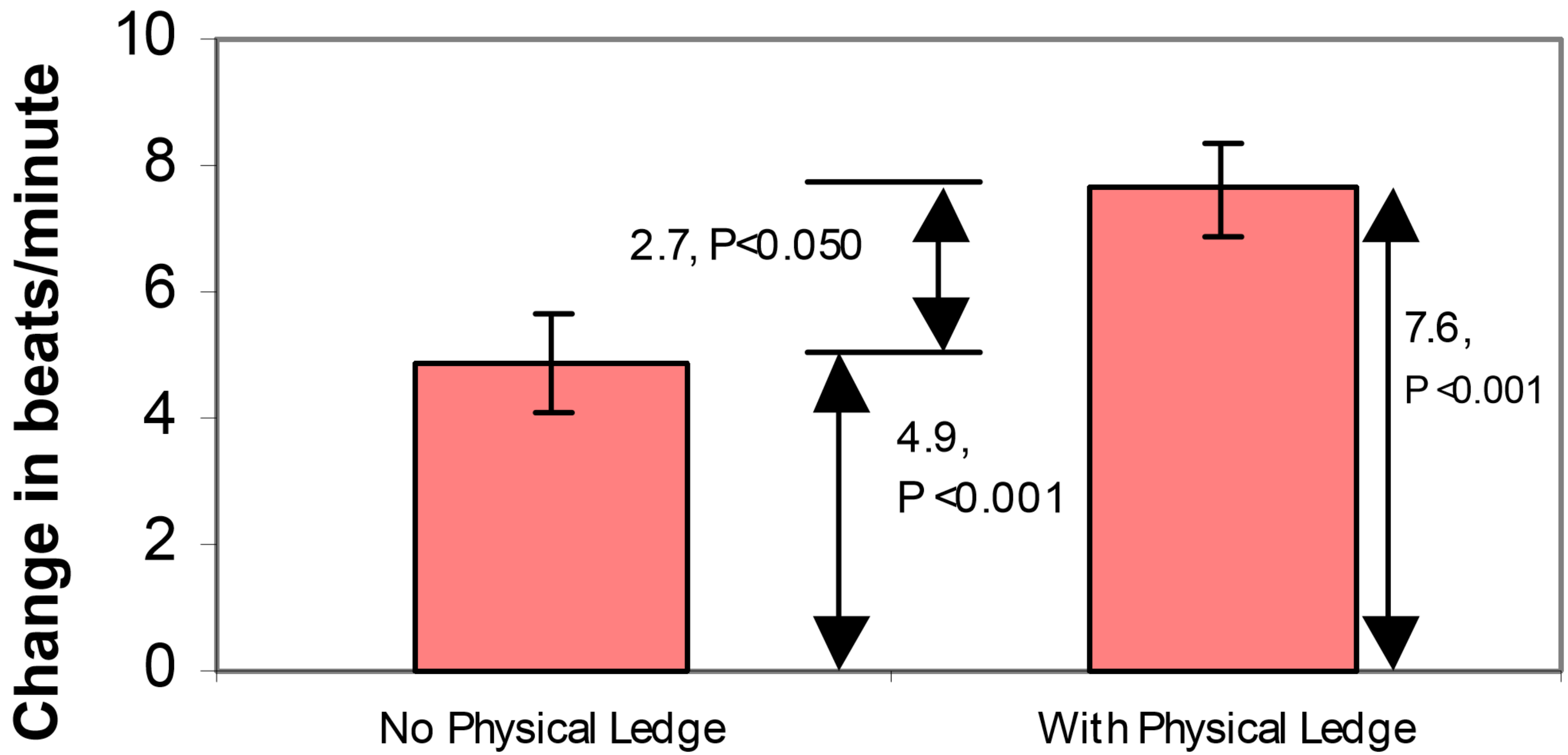
**Figure 3.  Subject wearing HMD and physiological monitoring**

**Figure 4. Subject in slippers with toes over 1.5-inch ledge.**

# Physiological Measures of Presence:

I was at UNC-CH, 2015, playing it.

# Heart Rate Changes: without vs. with a ledge



# Experimental Results

- We found that change in heart rate satisfied our requirements for a measure of presence, change in skin conductance did to a lesser extent, and that change in skin temperature did not. Moreover, the results showed that inclusion of a passive haptic element in the VE significantly increased presence and that for presence evoked: 30FPS > 20FPS > 15FPS.

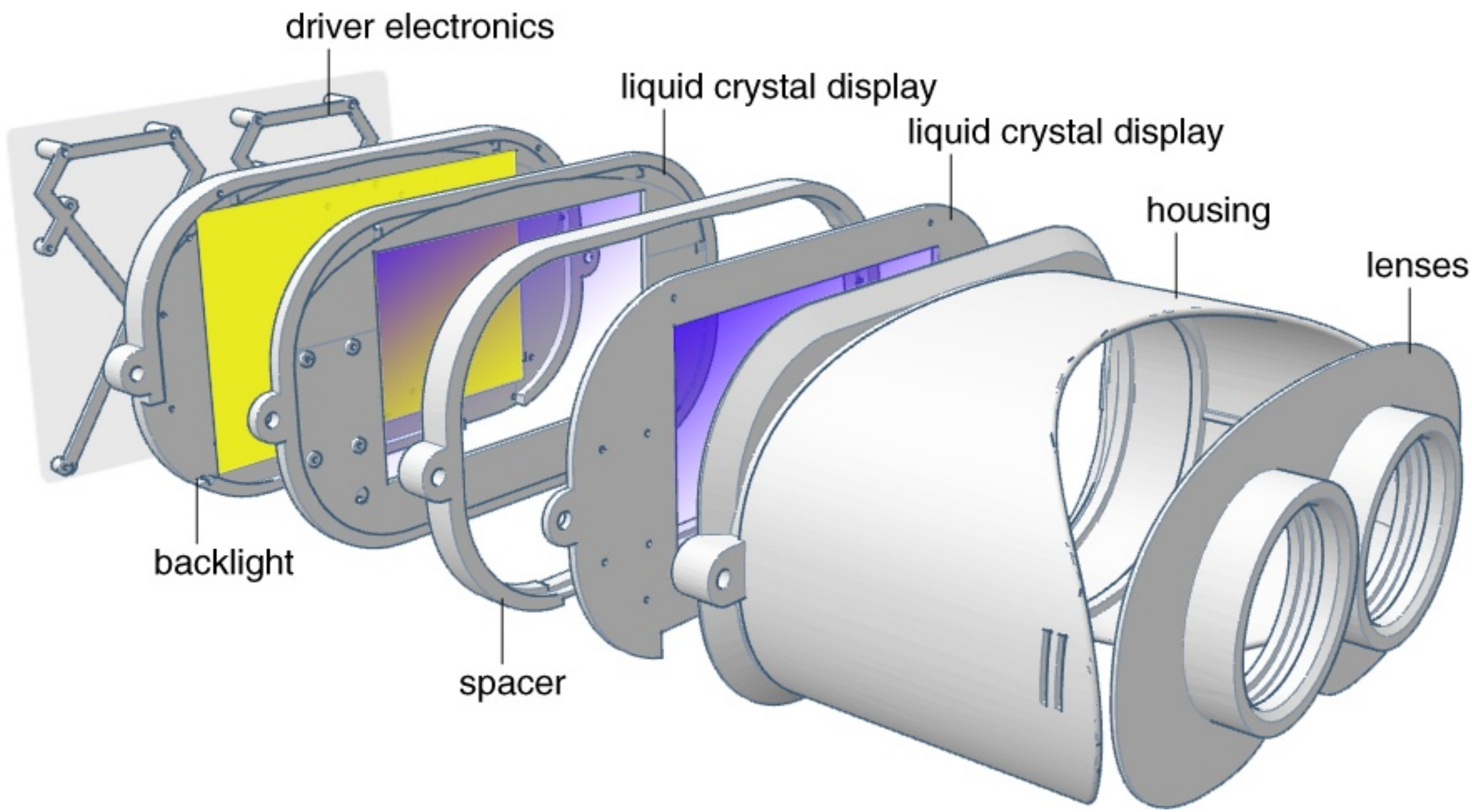
# Problem 3: fixed focus vs. variable focus:

- "**The Light Field Stereoscope: Immersive Computer Graphics via Factored Near-Eye Light Field Display with Focus Cues**",
  Fu-Chung Huang, Kevin Chen, and Gordon Wetzstein,
  Youtube Link
  *ACM SIGGRAPH 2015, Los Angeles*

- "**Eyeglasses-free Display: Towards Correcting Visual Aberrations with Computational Light Field Displays**",
  Fu-Chung Huang, Gordon Wietzstein, Brian Barsky, and Ramesh Raskar,
  - 10 World Changing Ideas 2014, Scientific American
  *ACM SIGGRAPH 2014, Vancouver*

# Front,middle,rear: three types of focus

# Innovation: vergence-accommodation conflict inherent to all stereoscopic displays



Problem 1: Display resolution (not to see pixels)
What is the best resolution in display in HMD?

- For example, for mobile device display:

For Google Cardboard VR HMD, if the field of view (angle) is 60 degrees, the required screen resolution is around 5700x5700,

For Oculus Rift2/Gear VR, or HTC Vive, the filed of view is 90-110 degrees, the required resolution should be 10Kx10K !

(Because in visual acuity: eye's ability to distinguish two points of light is limited to **1.5 – 2.0 mm at a distance of 10 meters**. (or 2 microns on the retina)).

# New types of display, other than LCD and OLED.

- Playnitrade Inc. for example

  can possibly provide a display of resolution 10Kx10K in a few years.

- *Semiconductor components for laser diodes (LD) , more density, brighter, and 85% efficiency in energy consumption.*

  *(UV-LED)*

- LCD has a energy efficiency of 5% only, while OLED is about 35%.

# Problem 4: Registration in AR

- What’s wrong in Pokemon Go (AR mode, with camera display)

Virtual objects cannot easily rest on chairs/table top.

- See our example AR application.

# Estimation in SDC 2014

**Concluding Remarks**

1. Will the current VR craze be once again followed by disappointment?
   Will we be wondering in a few years, "Whatever happened to … Virtual Reality"
2. VR easier than AR: display, tracking, rendering latency
3. VR has much better chance this time: Mass market makes all the difference
   - 1990s VR systems cost $ 50k or more
   - 2014: Oculus Rift DK-2 $ 400 + a PC
   - 2014: Samsung GearVR mobile HMD $ 199 + Galaxy Note 4
4. Potential for millions of sales:
   - Sufficient volume to support an industry of app developers, hardware add-ons, etc.
5. Big uncertainty: For what will millions of people use VR systems
   - Immersive video games + entertainment, live events + education + training + health +..
6. 2014 will be the historic turning point: from niche market to mass adoption

**Jump in !**

SDC2014

# Influence of the future smartphones, a prediction: Google Daydream project

1. In the past, GPUs in phones are not really important, VIDEO codecs are more important! (Flicker, Youtube Inc.)
2. Now, heterogeneous systems (CPU+GPU) are increasingly important, a must! (VR, AR)
3. New sensors (position sensor, roll sensor) needed for HCI, probably as additional NFC/Bluetooth devices.
4. Higher resolution (toward 4x by 4k x2)

# Application and opportunity: Apps, new sensors, higher resolution display

- Apps development, including health and medical care
- position sensors, or camera-based tracking device (using Church's algorithm): problem 2: Latency reduction
- Super-resolution display (eg. UV-LED), up to 10k by 10k
- Image processing and SOC for super-resolution.
- new type HCI (Finer pad, gesture control, new HCI, game pad with joystick using USB)
- form factors for HMD

# END of Part 1

- ”Duen-Huang Cave VR/AR Display”
- SCOPE+: One example of medical training application
- caTAR: eye surgery for Cataract removal (future predictions/imagination)
- Docomo Vision 2020
- MicroSoft’s Concept: Future Vision 2020
- Samsung’s vision: display

- What’s NOT really true here
- Magic Leap’s “whale in a gym” show
- JJ Lin’s show Chinese New Year 2017 (live broadcasting)

# A Stereoscopic Video See-Through Augmented Reality Microscope

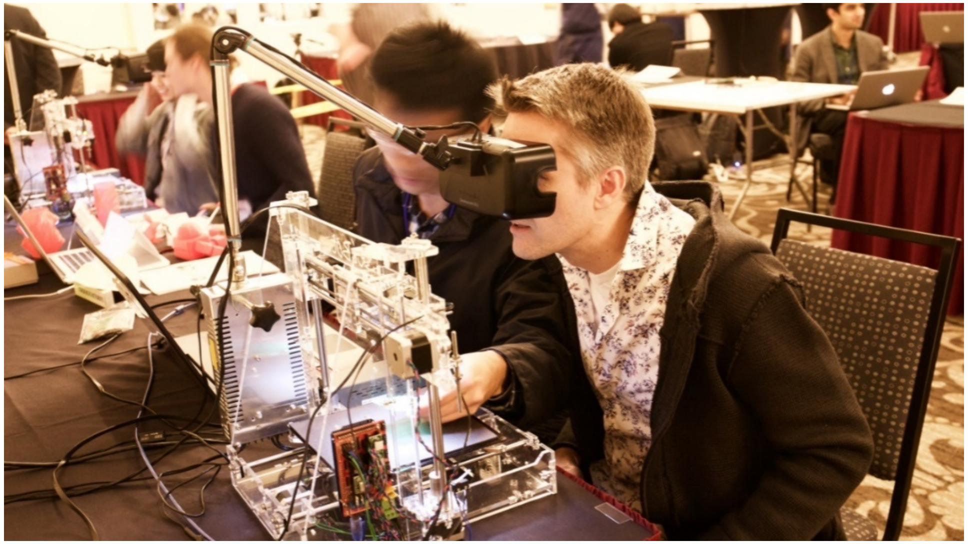
Yu-Hsuan Huang Tzu-Chieh Yu Pei-Hsuan Tsai
Yu-Xiang Wang Wan-Ling Yang 歐陽明(Ming Ouhyoung)

National Taiwan University

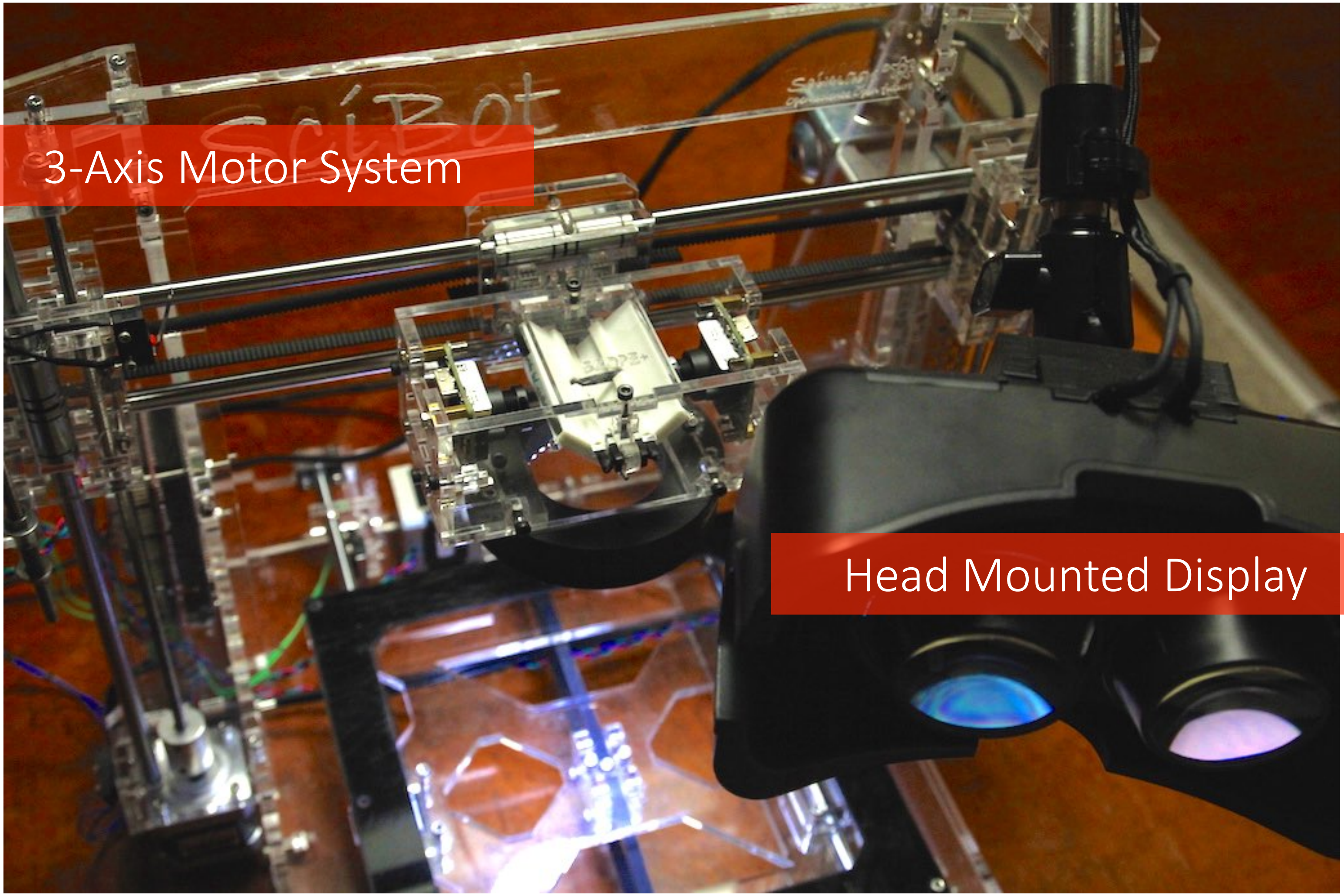
國立臺灣大學 National Taiwan University

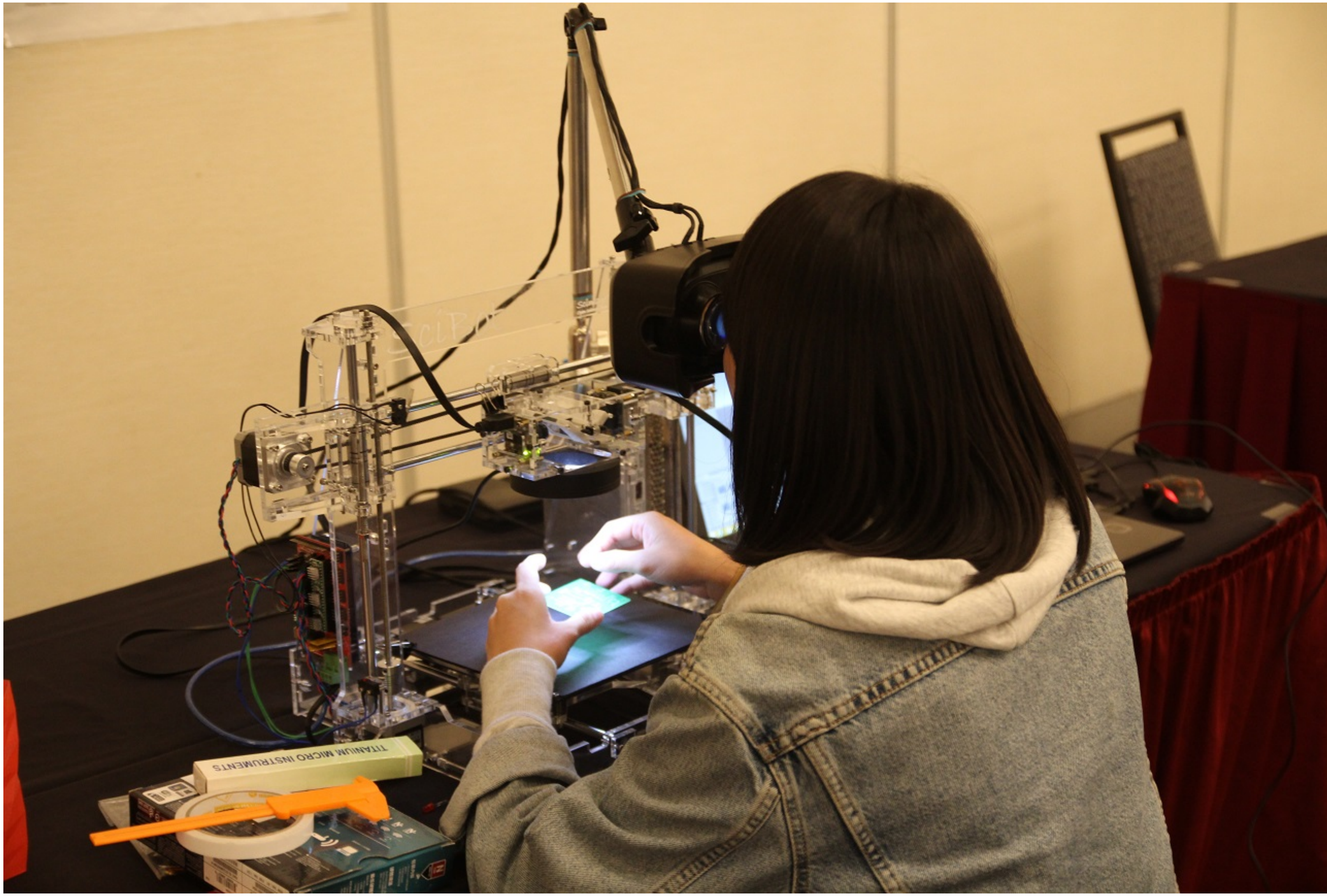
# Scope+:　won Best Demo　in ACM UIST 2015 Conference Demo Competition　!

Scope+ : A Stereoscopic Video See-Through Augmented Reality Microscope

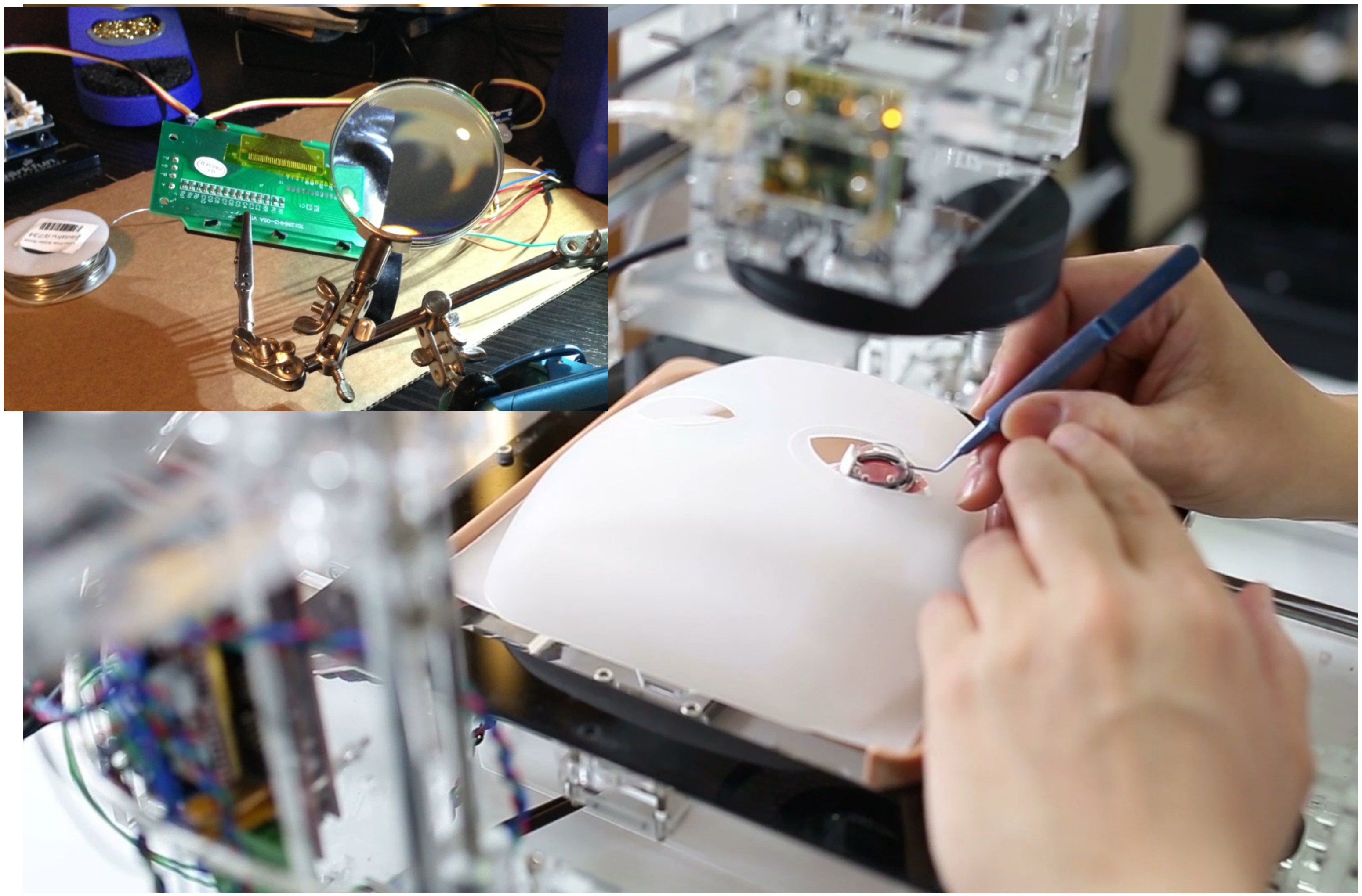


# Motor & Display System

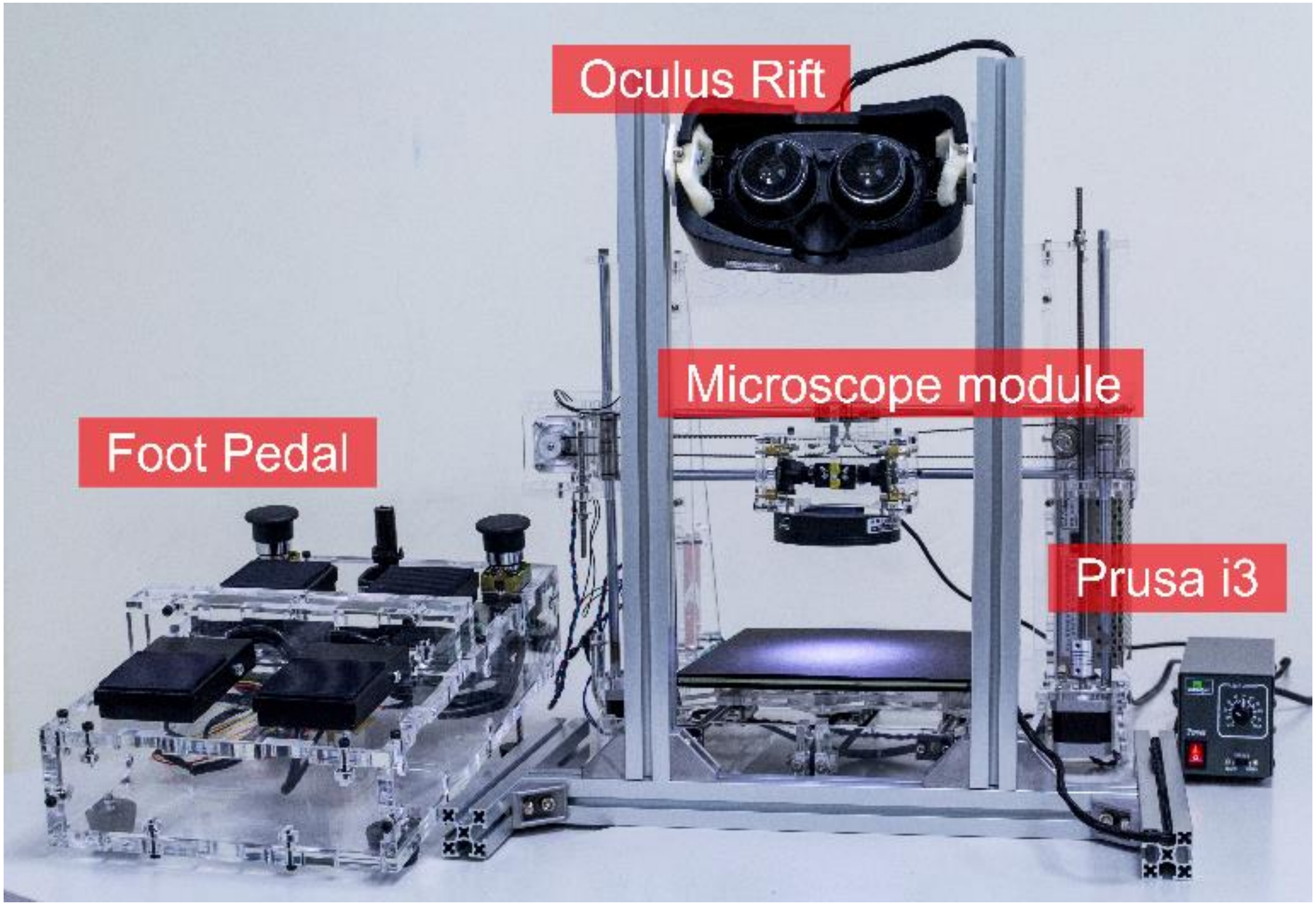



TITANIUM MICRO INSTRUMENTS

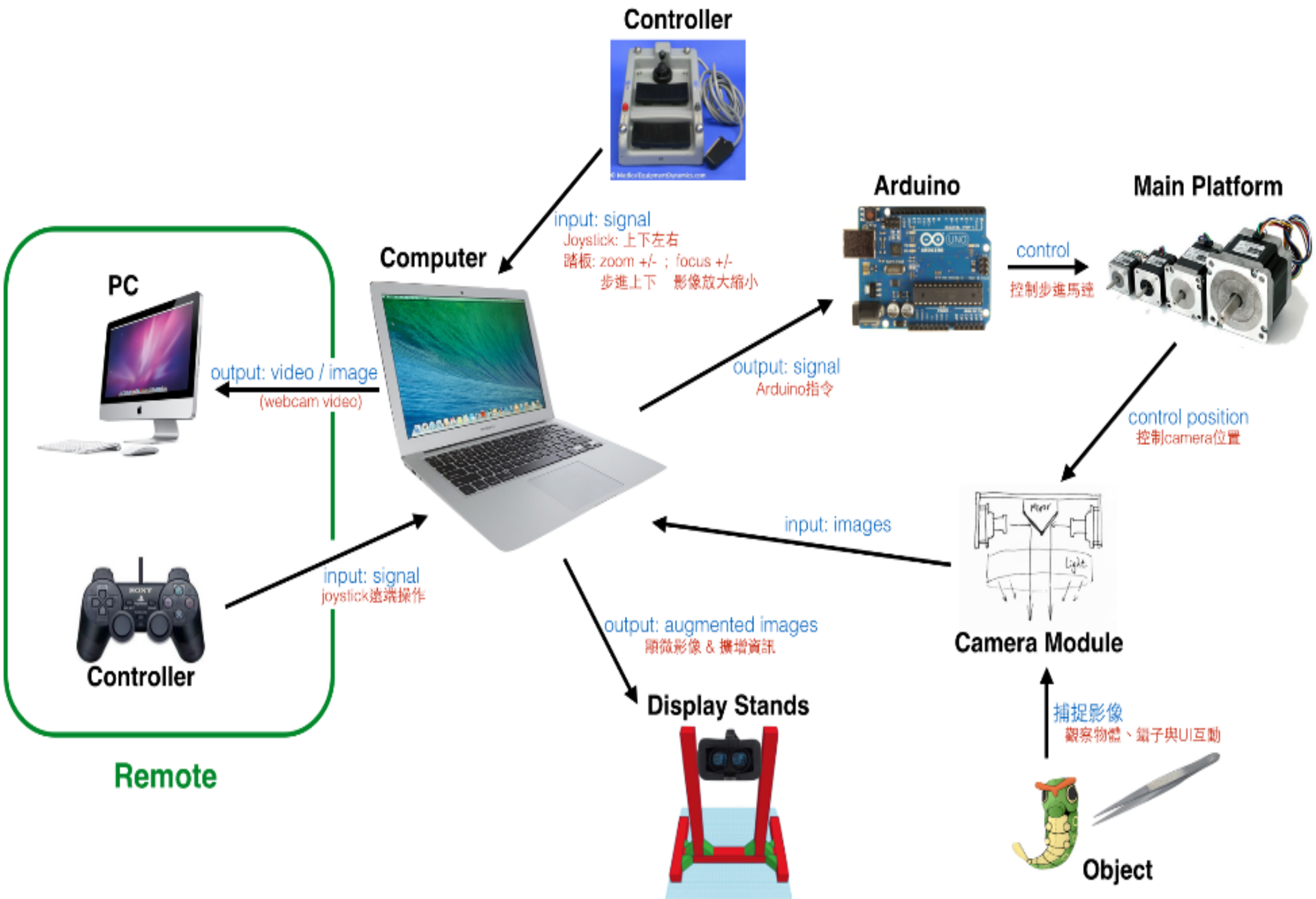
# Interactive Guidance



# *Scope+* hardware platform:



# *Scope+* System Architecture

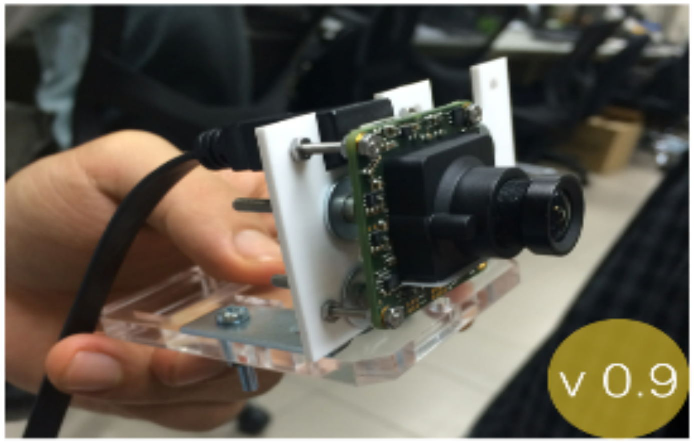


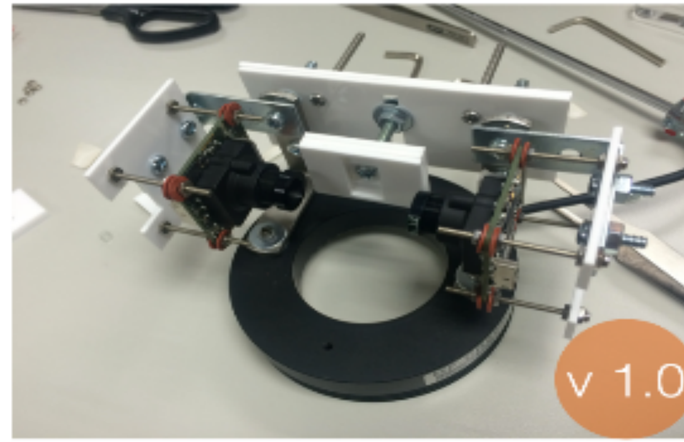
# Functions:

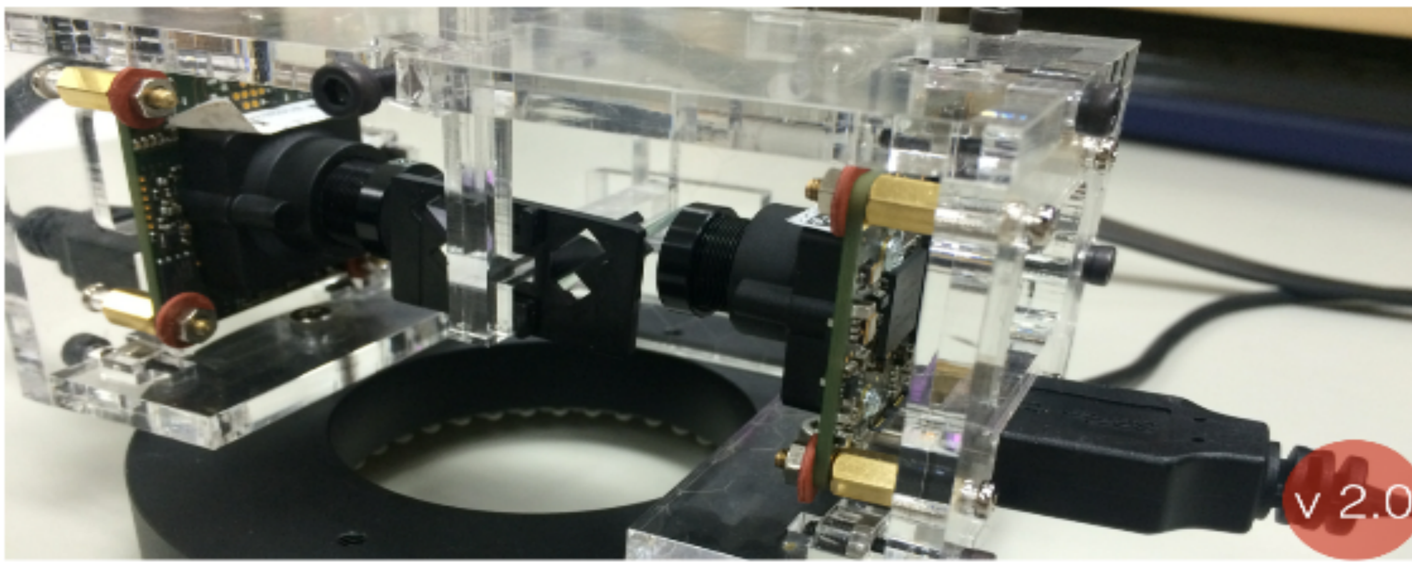
Reference: CatAR: A Novel Stereoscopic Augmented Reality Cataract Surgery Training System with 7-DOF Dexterous Instruments Tracking Technology (Siggraph Asia 2016, VR Showcase)

- Stereoscopic augmented reality cataract surgery training system.
- The spatial resolution is 0.015mm
- It provides 7 degree-of-freedom dexterous instruments tracking ability by utilizing infrared optical based tracking system with 2 cameras and 1 reflective marker only.

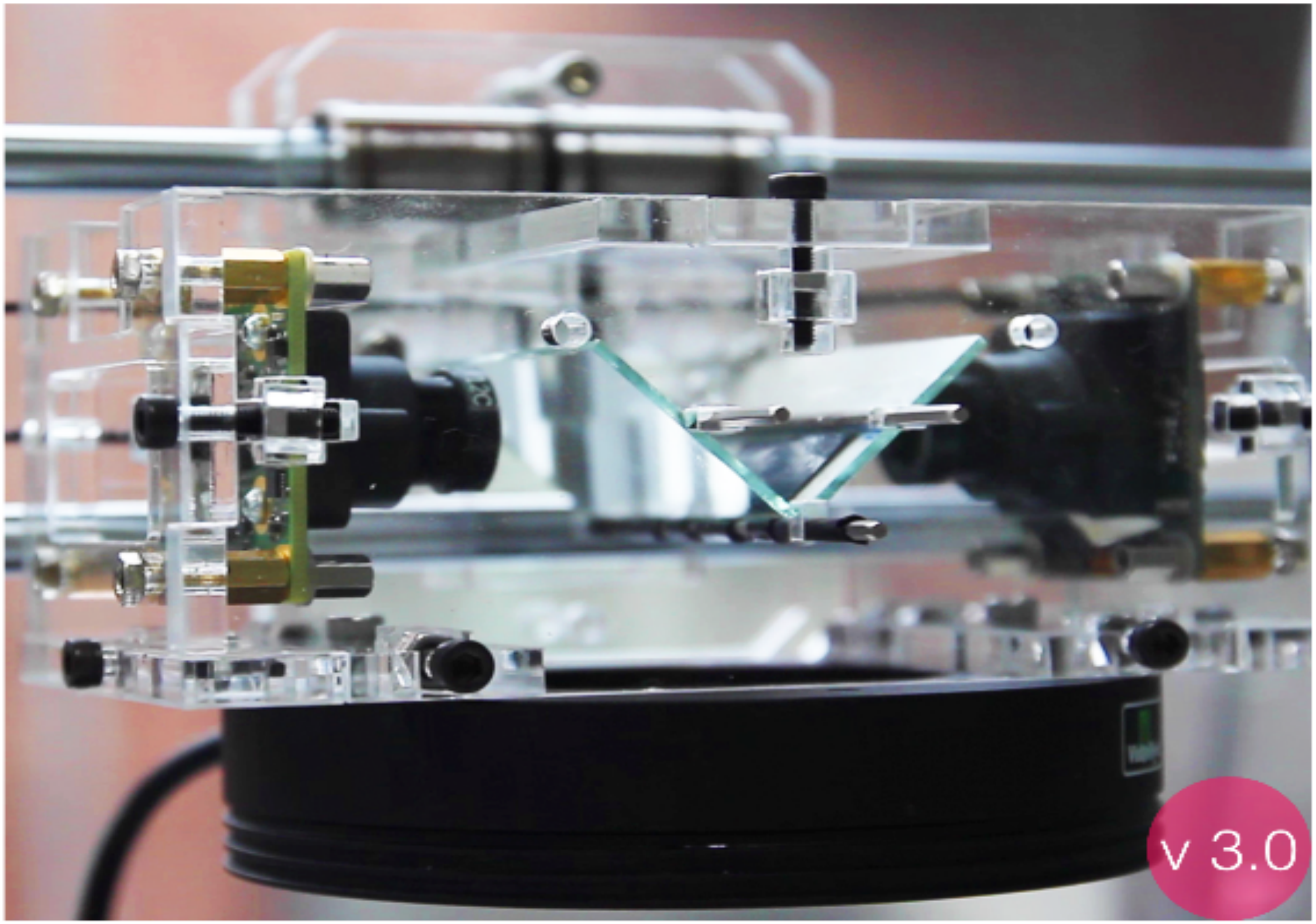
# Camera lenz assembly



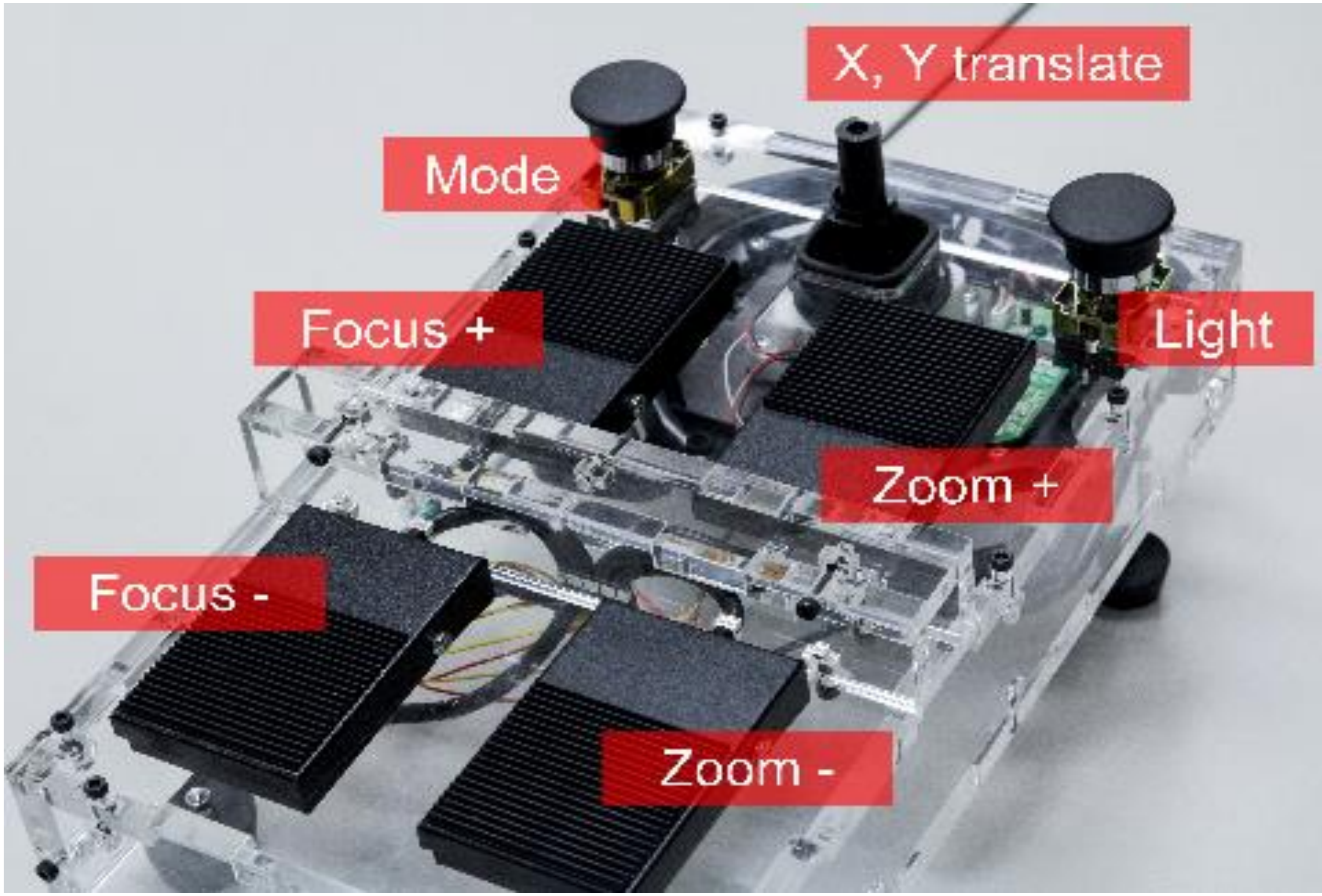



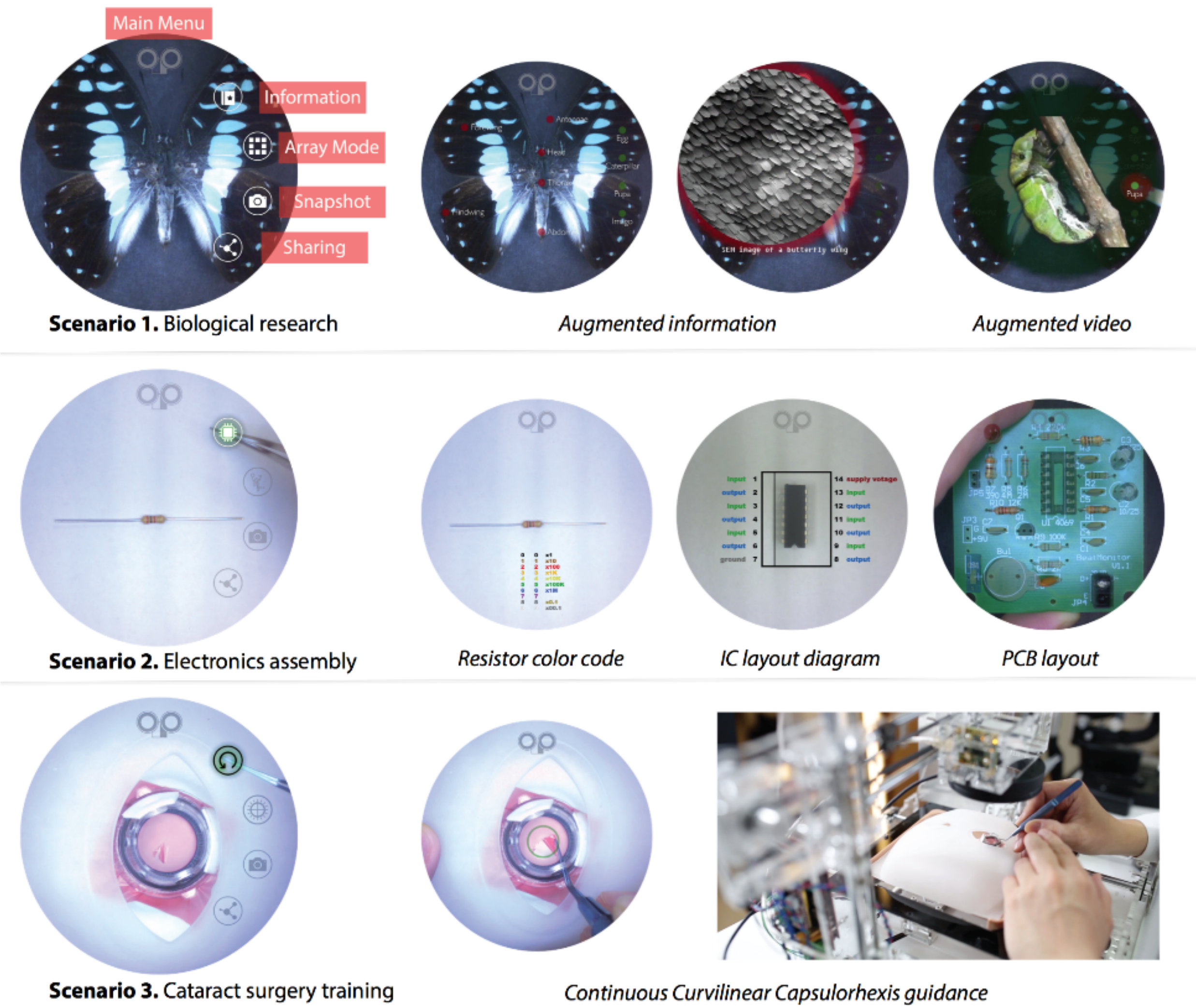
# Near-field augmented reality



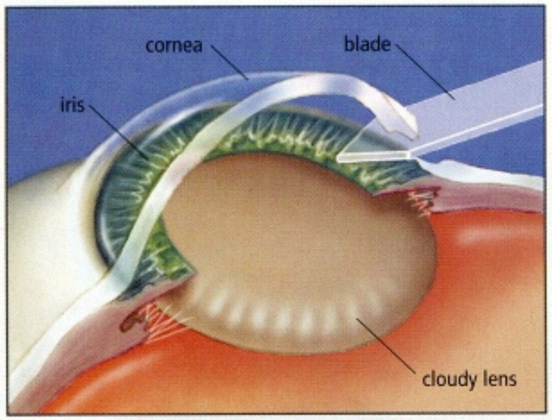
# Foot Pedal Controller: to help both hands



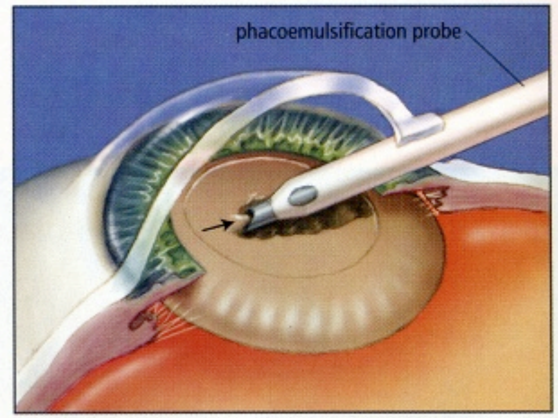
# Applications (DEMO): 1. Butterfly observation, 2. Circuit board assembly 3. Eye surgery training



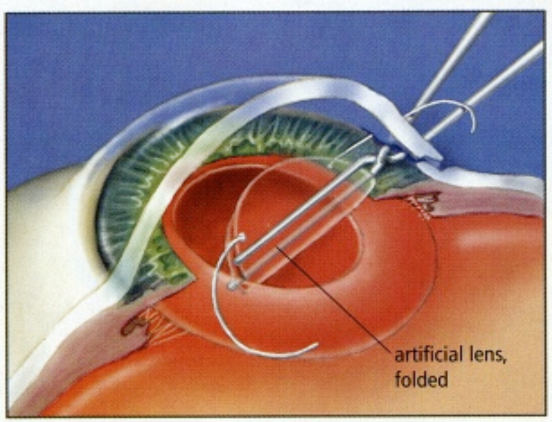
# Cataract surgery



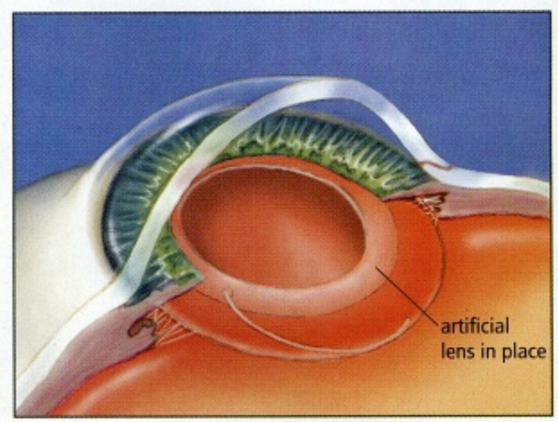

1. Incision: A small incision, approximately 3mm in width, is made at the corneal margin.




2. Emulsification: Phacoemulsification probe is inserted through corneal incision and ultrasound breaks cataract up into microscopic fragments, which can then be aspirated using the probe tip.

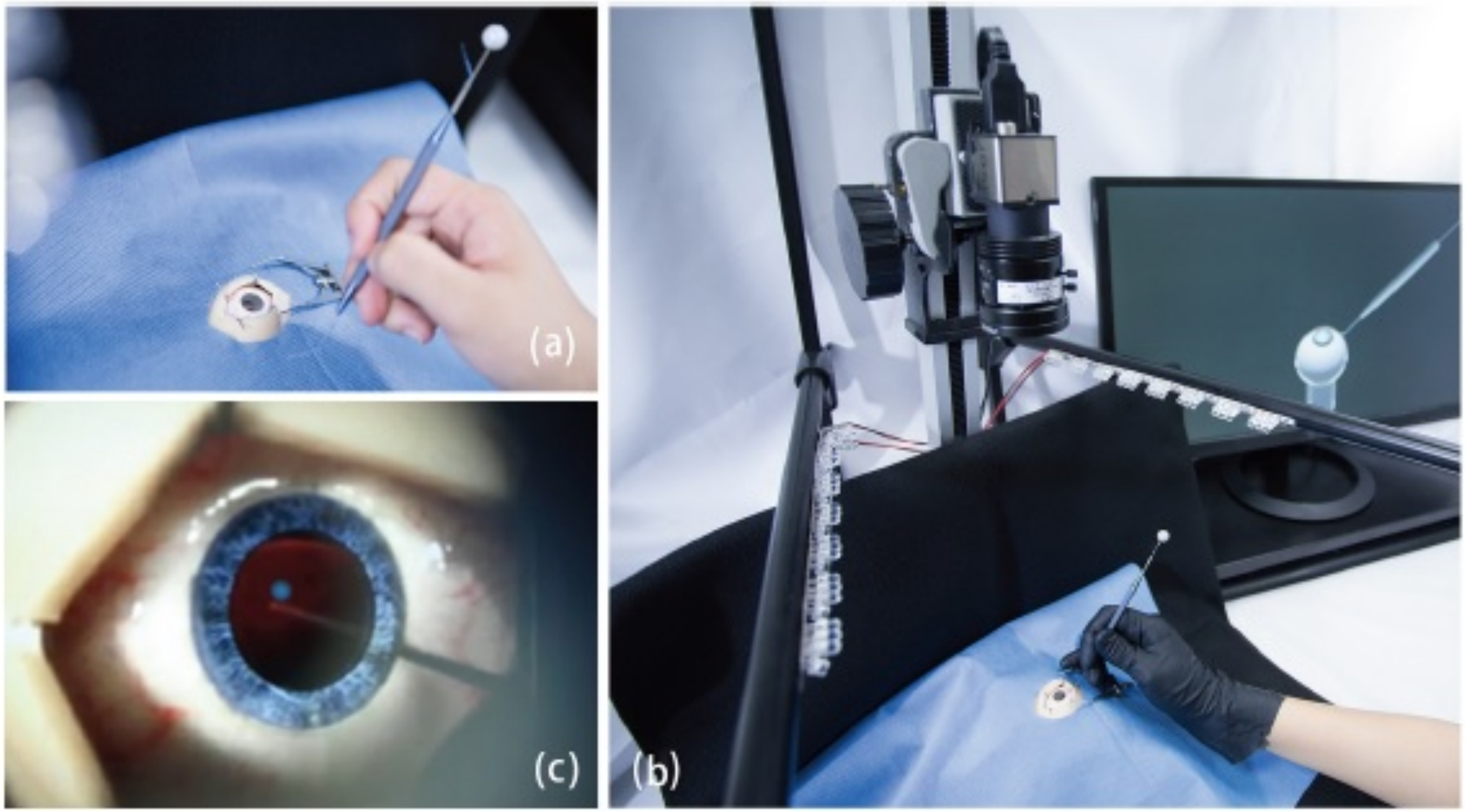



3. Intraocular Lens Implant: The artificial foldable intraocular lens is inserted and, once inside, the lens unfolds.




4. Result: The new lens is in place, the small incision heals naturally without the need for sutures, and vision is restored.

# Eye surgery AR simulator (DEMO 2)



# Surgical Instrument Motion Detection

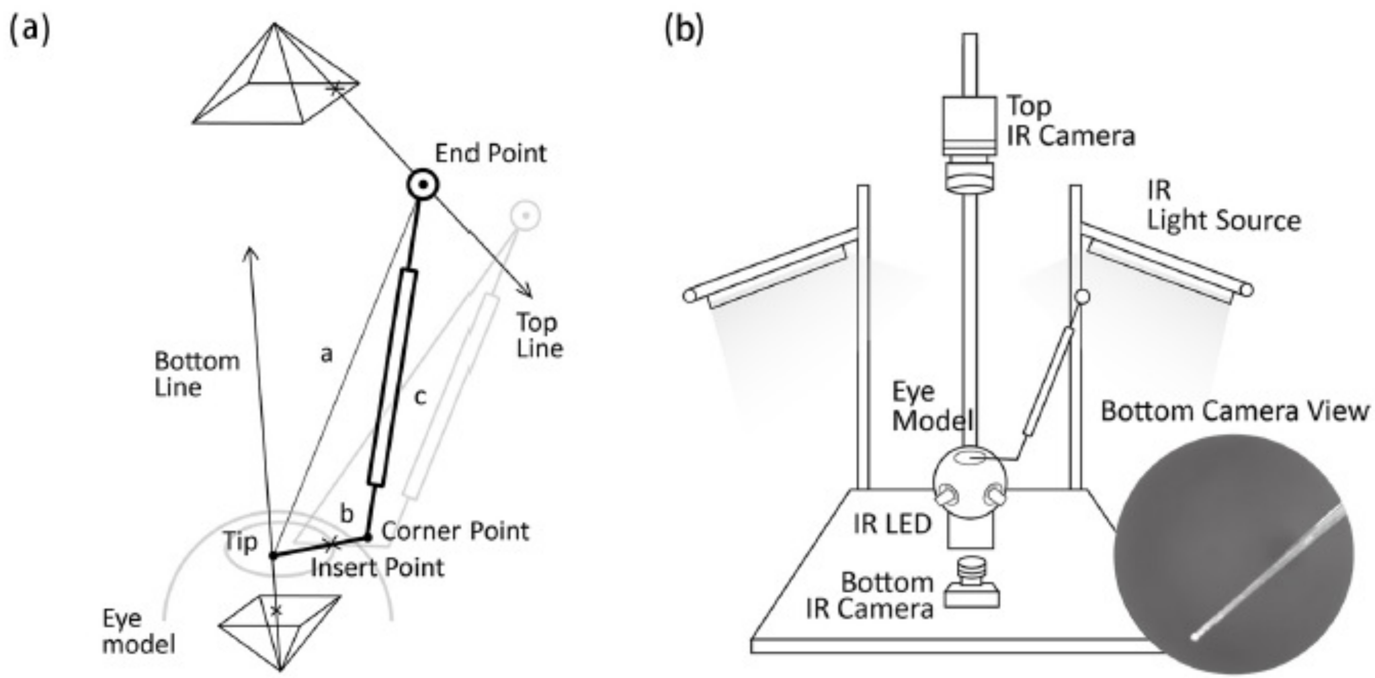
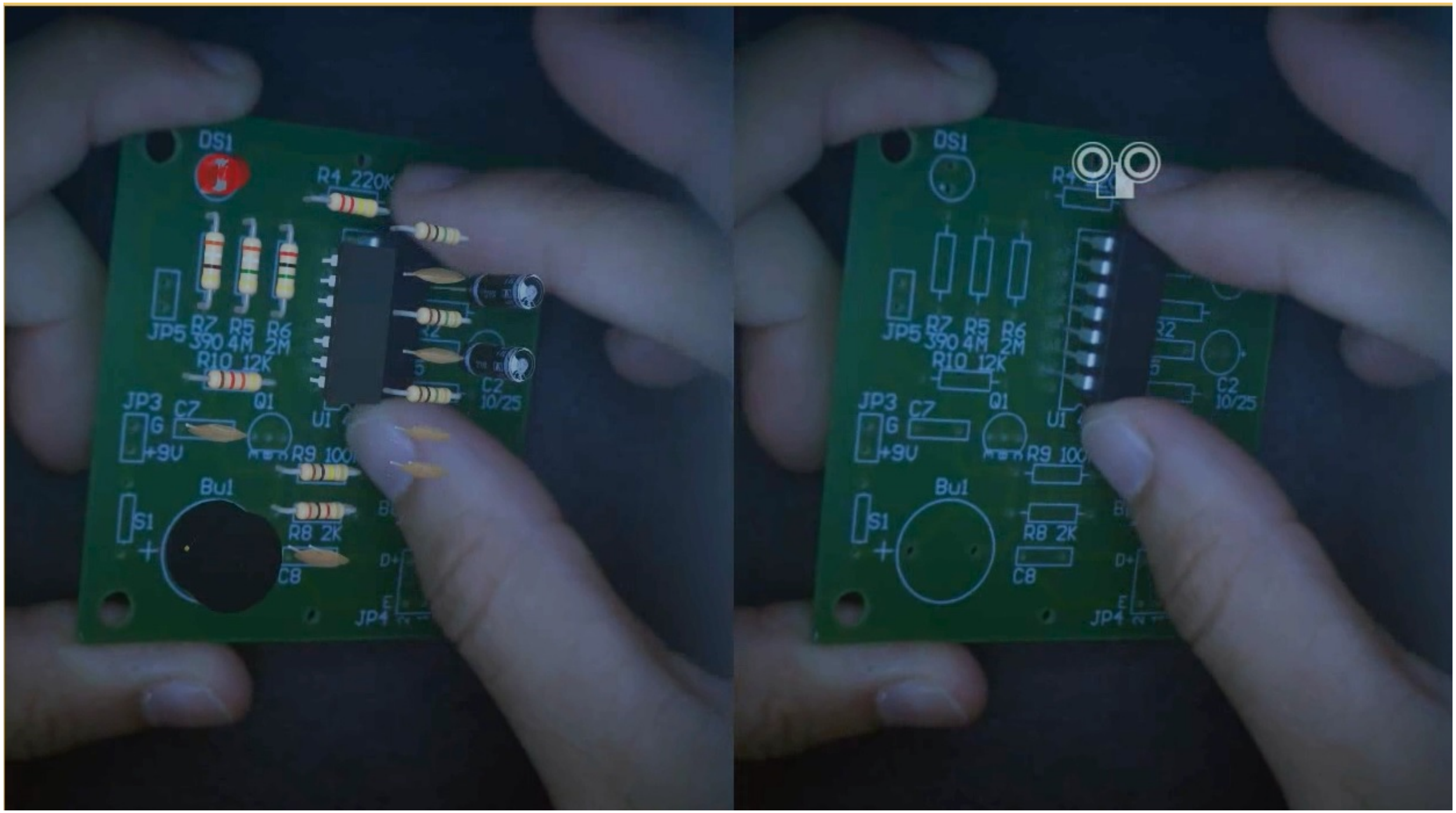



Figure 1: (a)Geometry of solving the instrument pose (b)System components.

# Registration of Virtual Objects with Real Ones: left eye view (circuit board with virtual elements), and right eye view




[Youtube: https://www.youtube.com/watch?v=vV83pWR4Dko&feature=youtu.be](https://www.youtube.com/watch?v=vV83pWR4Dko&feature=youtu.be)

DEMO

# END
# Reference for video

Short VIDEO, Circuit Board
https://www.youtube.com/watch?v=vV83pWR4Dko&feature=youtu.be
Long VIDEO, SCOPE+
https://www.youtube.com/watch?v=rmohFEAreUs&feature=youtu.be

https://01.org/zh/intel-deep-learning-framework?langredirect=1

# AR + VR

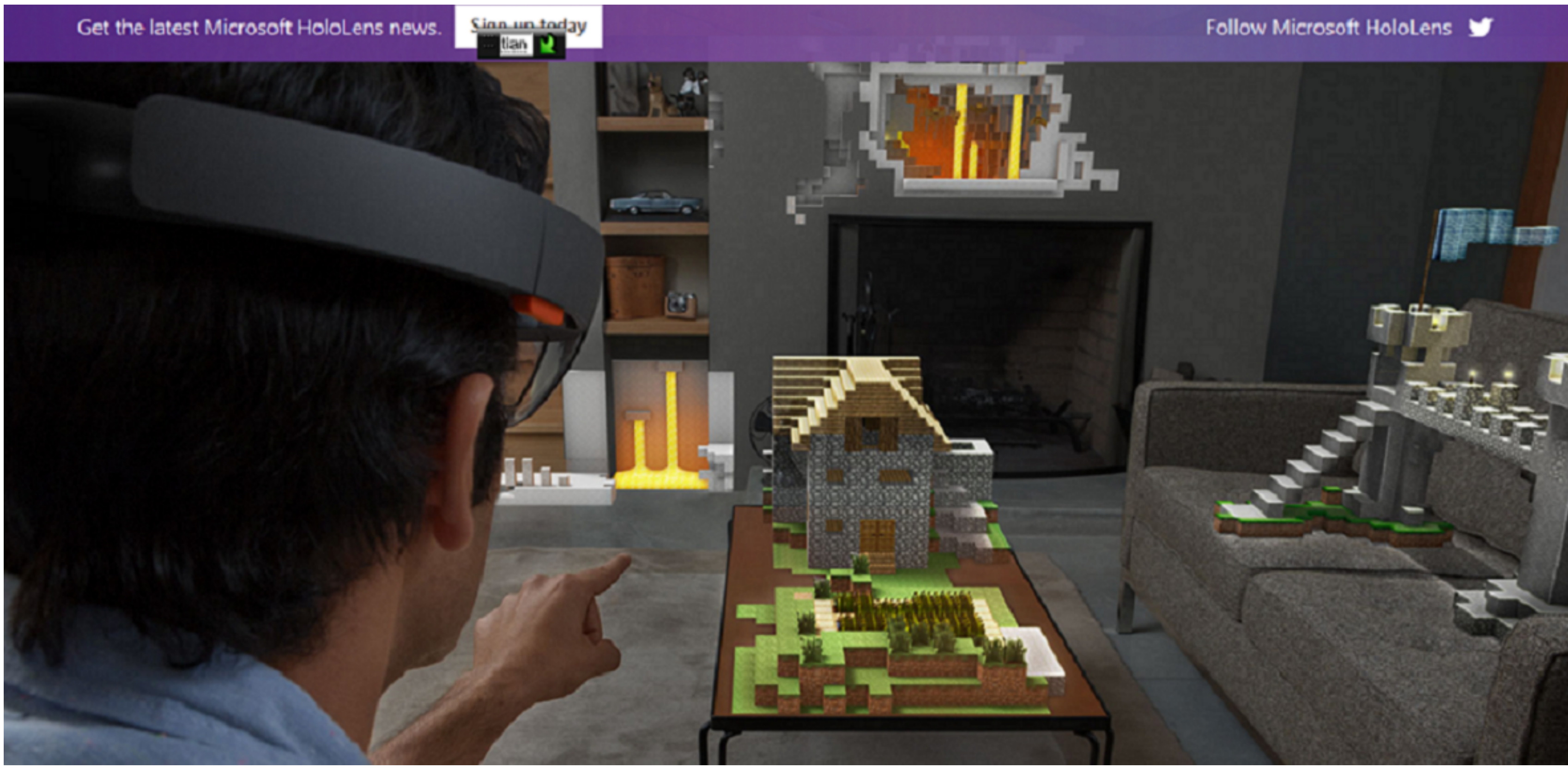
- Microsoft Inc. HoloLens Project, Windows 10, Holographics Live Demo
- https://www.youtube.com/watch?v=kCMxBw-utEY&feature=youtu.be

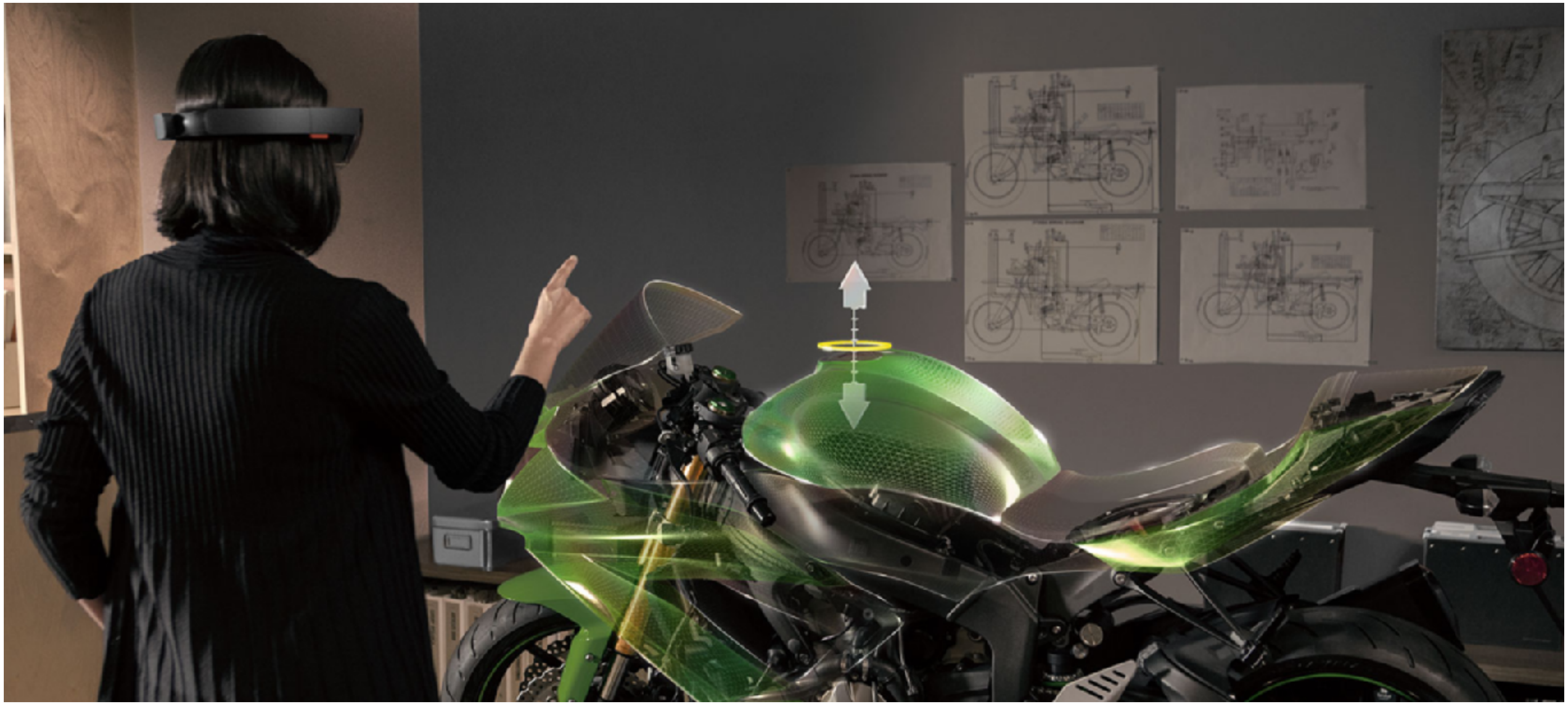
- https://www.youtube.com/watch?v=vsKMi1377cU

.NTU MediaTek collaborative project:  concept demo (Taiwan 2025)

D:\Ming_1\NSC\2012_前瞻技術產學大聯盟\Final_2013_4_10\2017_5_短片宣導/1003_聯發科_Final_Version.mp4

# HoloLens Project

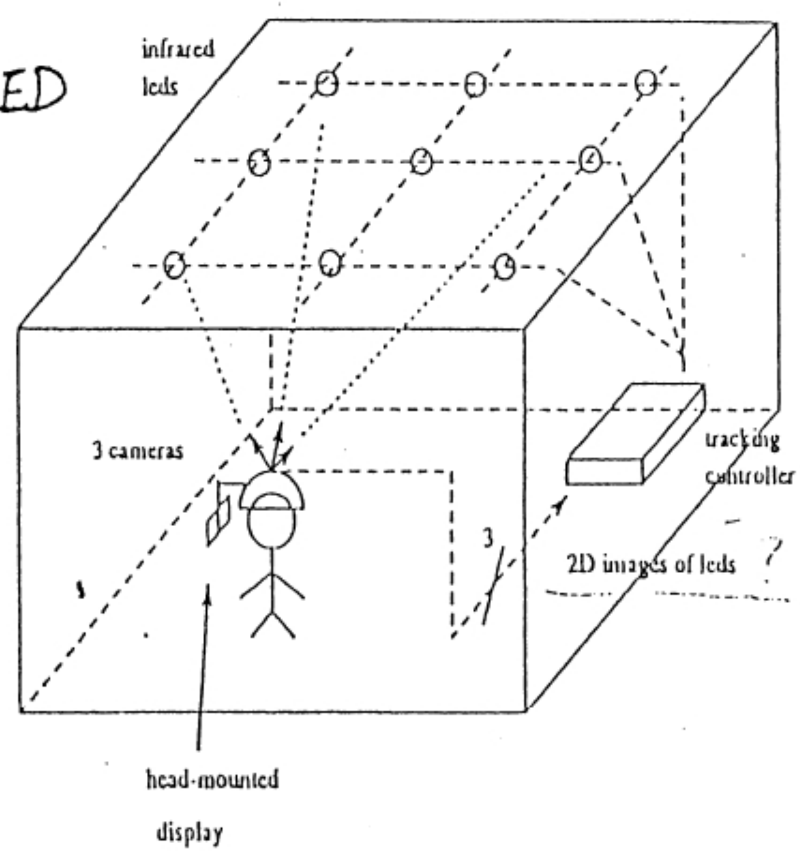




# Optical Trackers
## Environment setup

- Outside-in vs Inside-out optical trackers
- Environment

LED



# Algorithms: Inferring 3D position

- Inferring 3D position from 2D image

  $(X_1, Y_1, Z_1, 1)$: point A in 3D, $(x_1, y_1, 1)$: point a in 2D

  $\Rightarrow [X_1, Y_1, Z_1, 1]\ M_{4x3} = [x_1, y_1, 1]$, solve $M_{4x3}$

- 12 unknowns in M, each 3D point provides 2 independent constrains => 6 points

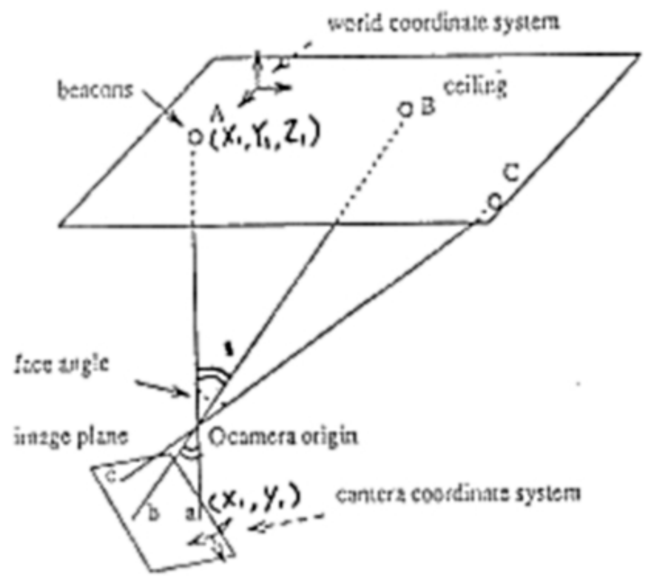



Figure 2: Church's algorithm

# Algorithms: Inferring 3D position

**Church(1945) method: modified by iterative converging.**

3 points, iterative method

$\angle AOB = \angle aOb$, guess point O's 3D position

in camera coordinate: $O(0, 0)$, $a(x_1, y_1)$, $b(x_2, y_2)$

in world coordinate: $O(X, Y, Z)$, $A(X_1, Y_1, Z_1)$, $B(X_2, Y_2, Z_2)$

compute $\angle aOb = \cos^{-1}(Oa \bullet Ob / |Oa||Ob|)$

same as $\angle AOB = \cos^{-1}(OA \bullet OB / |OA||OB|)$

if $(\angle aOb - \varepsilon) < \angle AOB < (\angle aOb + \varepsilon)$, add an adjustment:

$diff = | \angle aOb - \angle AOB |$

$(\Delta X, \Delta Y, \Delta Z) = (\partial diff / \partial X, \partial diff / \partial Y, \partial diff / \partial Z)$

$\Rightarrow O(X', Y', Z') = O(X + \Delta X, Y + \Delta Y, Z + \Delta Z)$

# Algorithms: System errors

- Result
  - In camera coordinate
    - long focal length
    - large separation between image points
    - high resolution of photodiode
- In world coordinate
  - large separation between beacons