CSE 190: Virtual Reality Technologies

LECTURE #13: VR TRACKING

Announcements

Homework project 3

- Late grading this Friday, May 24th at 2pm

Homework project 4

- To be released this Friday
- Teams of two allowed

Midterm exam this Thursday, May 23rd

- In-class during lecture
- Closed-book
- Allowed: pen, pencil, eraser, ruler, scrap paper
- Follows the format of last two years' exams (can be found on course schedule)

Summer Job

Work with Kelly Courtney, post-doc in psychiatry department

Lead development of Unity application

Goal: study addiction (alcohol, tobacco)

Hardware: FOVE headset with eye tracking and HTC Vive controllers

Glass Enterprise Edition 2

Announced May 20, 2019

Price: $999

Qualcomm Snapdragon XR1

Supports computer vision and advanced machine learning capabilities

Safety frames from Smith Optics

Bigger battery and "other upgraded components"

Runs on Android, with support for Android Enterprise Mobile Device Management

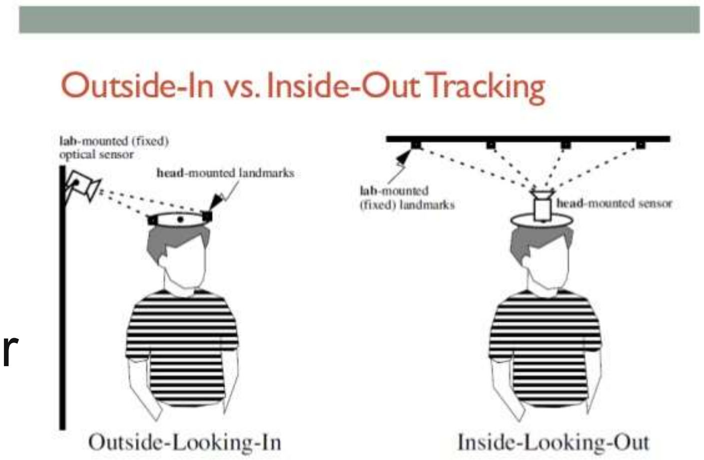
Types of Positional Tracking

“**Outside-in tracking**”: external sensors, cameras, or markers are required (i.e., tracking constrained to specific area)

- Used by Oculus Rift, HTC Vive

“**Inside-out tracking**”: camera or sensor is located on HMD, no need for other external devices to do tracking (but can still have them)

- Simultaneous localization and mapping (SLAM) – classic computer vision problem



Inside-out Tracking

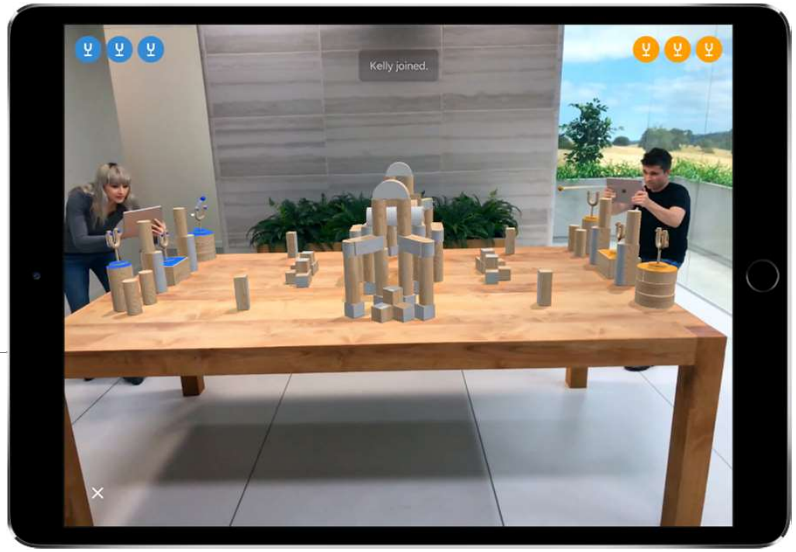
Marker-less inside-out tracking

Examples: Microsoft HoloLens, Mixed Reality HMDs, Oculus Quest, Oculus Rift S

Lenovo Mixed Reality

Oculus Quest

Apple ARKit



ARKit 1 supported by any device with iOS 11

ARKit 2 available since iOS 12

Persistent AR Experiences:

- Provide AR experiences that persist between sessions, and can be resumed at a later time

Shared AR Experiences:

- Multiple users can use their iOS device to simultaneously view AR experiences or play multiplayer games. Bystanders can spectate AR games being played by multiple participants.

Object Detection and Tracking:

- ARKit 1.5 added support for 2D image detection, letting you trigger an AR experience based on 2D images like posters, artwork, or signs. ARKit 2 offers full 2D image tracking, so you can incorporate movable objects like product boxes or magazines into your AR experiences. ARKit 2 also adds the ability to detect known 3D objects like sculptures, toys, or furniture.

Demo: https://www.youtube.com/watch?v=-o7qr1NpeNI

Midterm Results

	Spring 2019	Spring 2018
Average	65.3	65.9
Median	68.0	65
Standard Deviation	8.9	5.7
Highest Score	79.5	74.5
Lowest Score	40.5	50

Google ARCore

Motion tracking:

- understand and track the phone's position relative to the world

Environmental understanding:

- detect the size and location of all type of surfaces: horizontal, vertical and angled surfaces like the ground, a coffee table or walls

Light estimation:

- estimate the environment's lighting conditions

Video:

- https://www.youtube.com/watch?v=ttdPqly4OF8

Outside-in Tracking

mechanical tracking

ultra-sonic tracking

magnetic tracking

optical tracking

GPS

WiFi positioning

marker tracking

Positional Tracking - Optical

- track active (near IR) LEDs with cameras

OR

- track passive retro-reflectors with IR illumination around camera

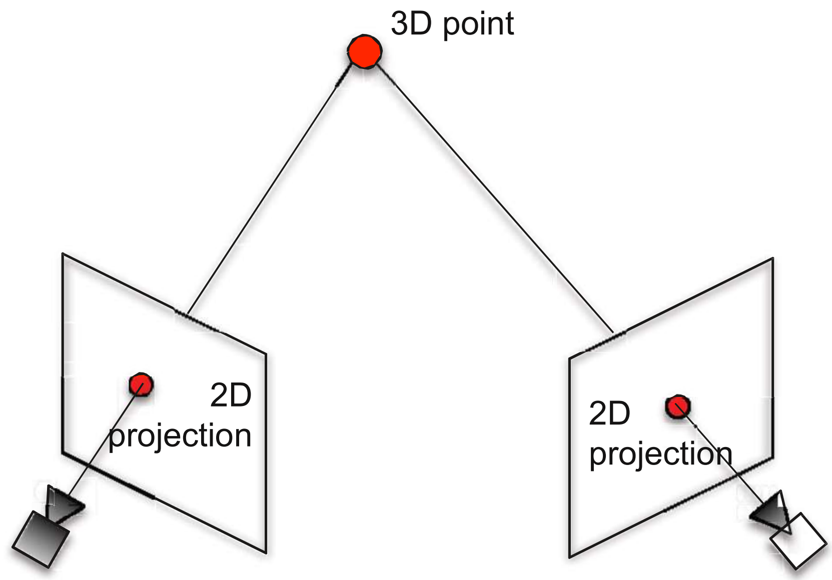
- both Oculus Rift and HTC Vive come with optical tracking

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

Positional Tracking - Optical

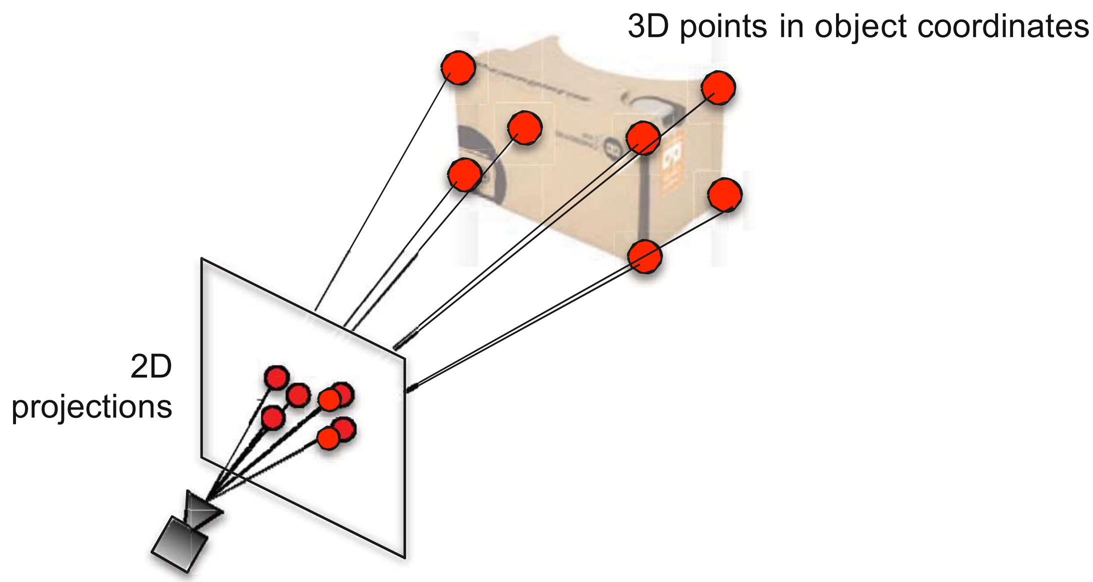
- for tracking individual 3D points, multi-camera setups usually use triangulation

- this does not give us the pose (rotation & translation) of camera or object yet



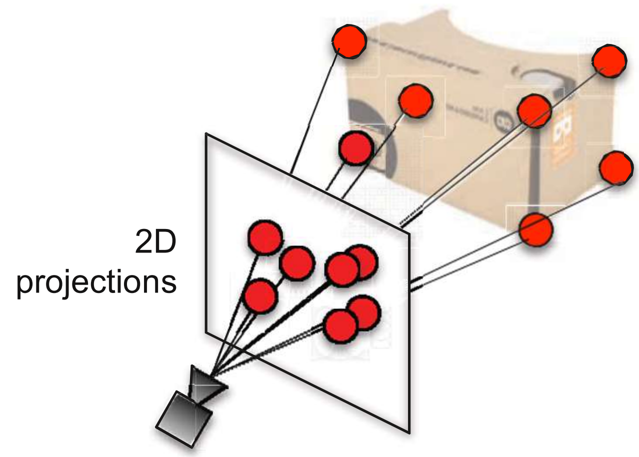
Positional Tracking - Optical

- for pose tracking, we need to track multiple 3D points with known relative coordinates



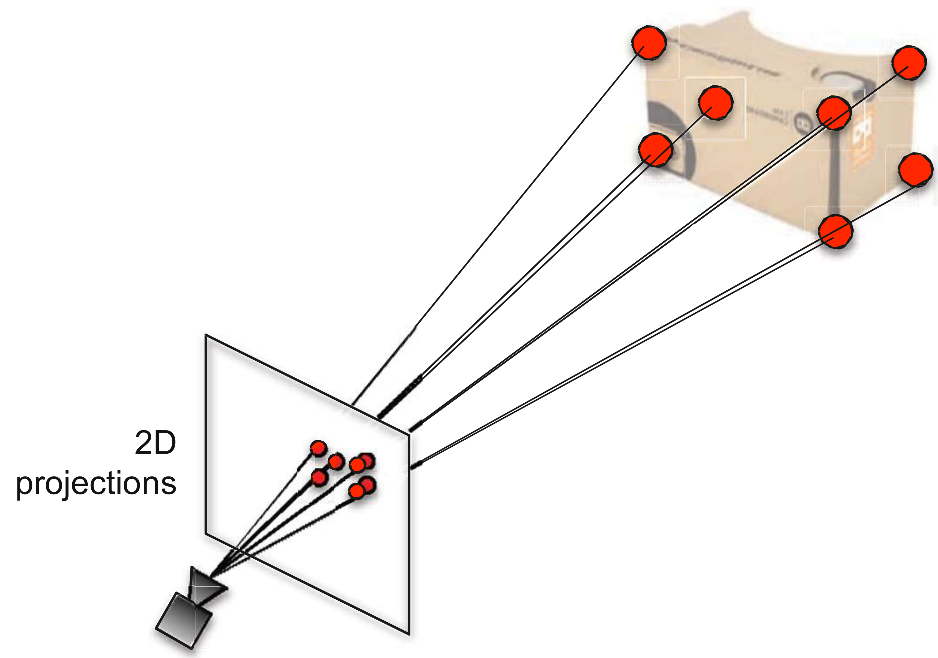
Positional Tracking - Optical

- when object is closer, projection is bigger



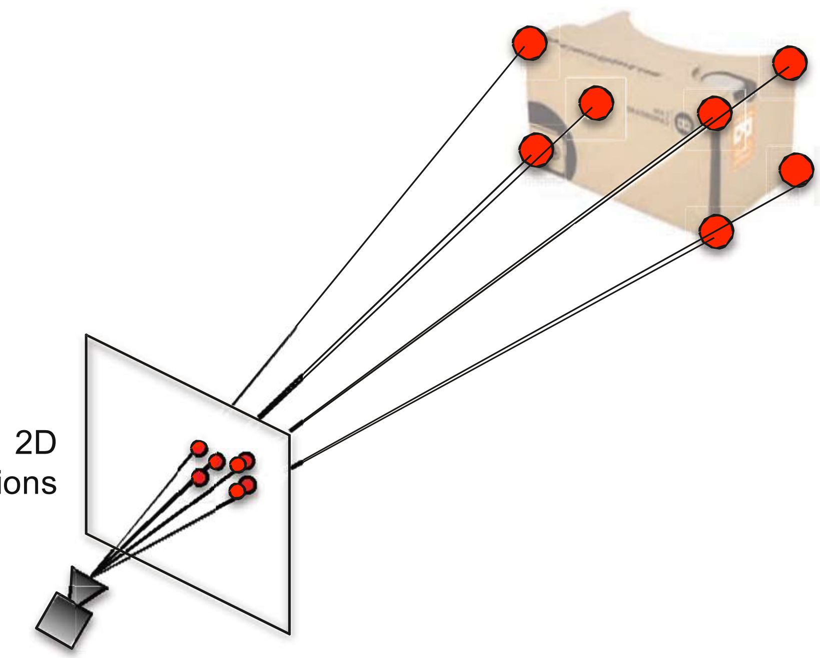
Positional Tracking - Optical

- when object is father, projection is smaller



Positional Tracking - Optical

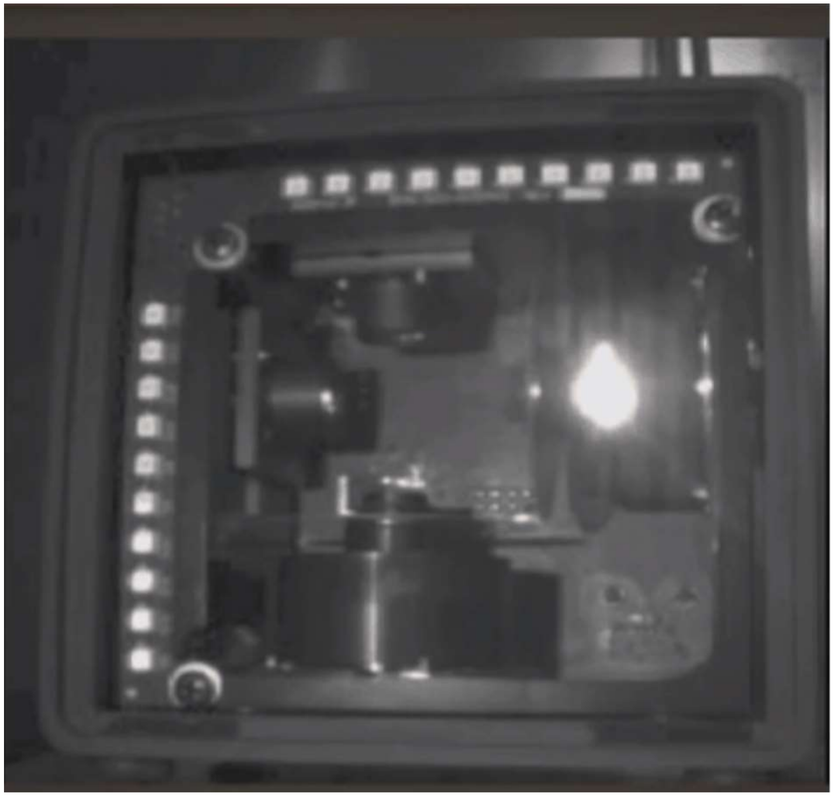
- pose estimation via optimization
- nonlinear least squares problem

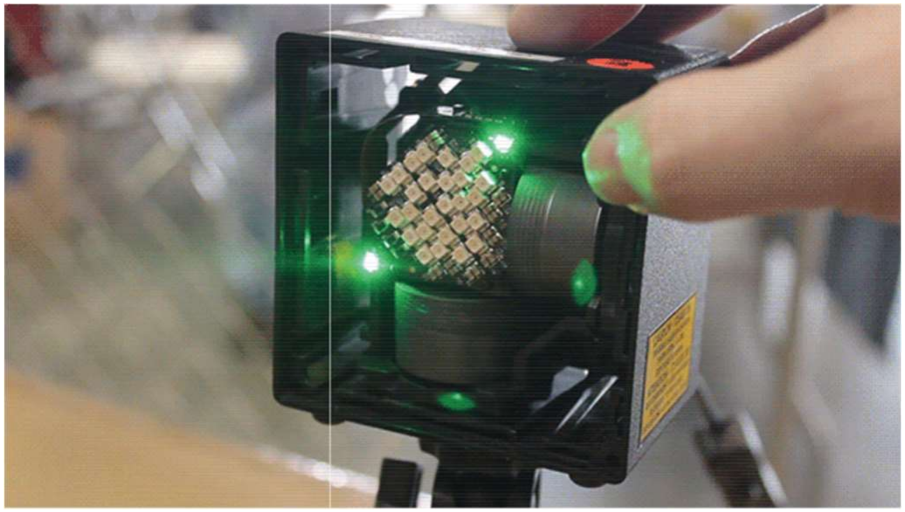


$$\underset{\{R,T\}}{\text{minimize}} \left\| \underbrace{\left(p_1^{2D}, p_2^{2D}, \ldots, p_N^{2D}\right)}_{\text{observed 2D points}} - f\left(\underbrace{p_1^{3D,\,object}, p_2^{3D,\,object}, \ldots, p_N^{3D,\,object}}_{\text{known 3D points}}, \underbrace{R, t}_{\text{unknown pose}}\right) \right\|_2^2$$

observed 2D points known 3D points unknown pose

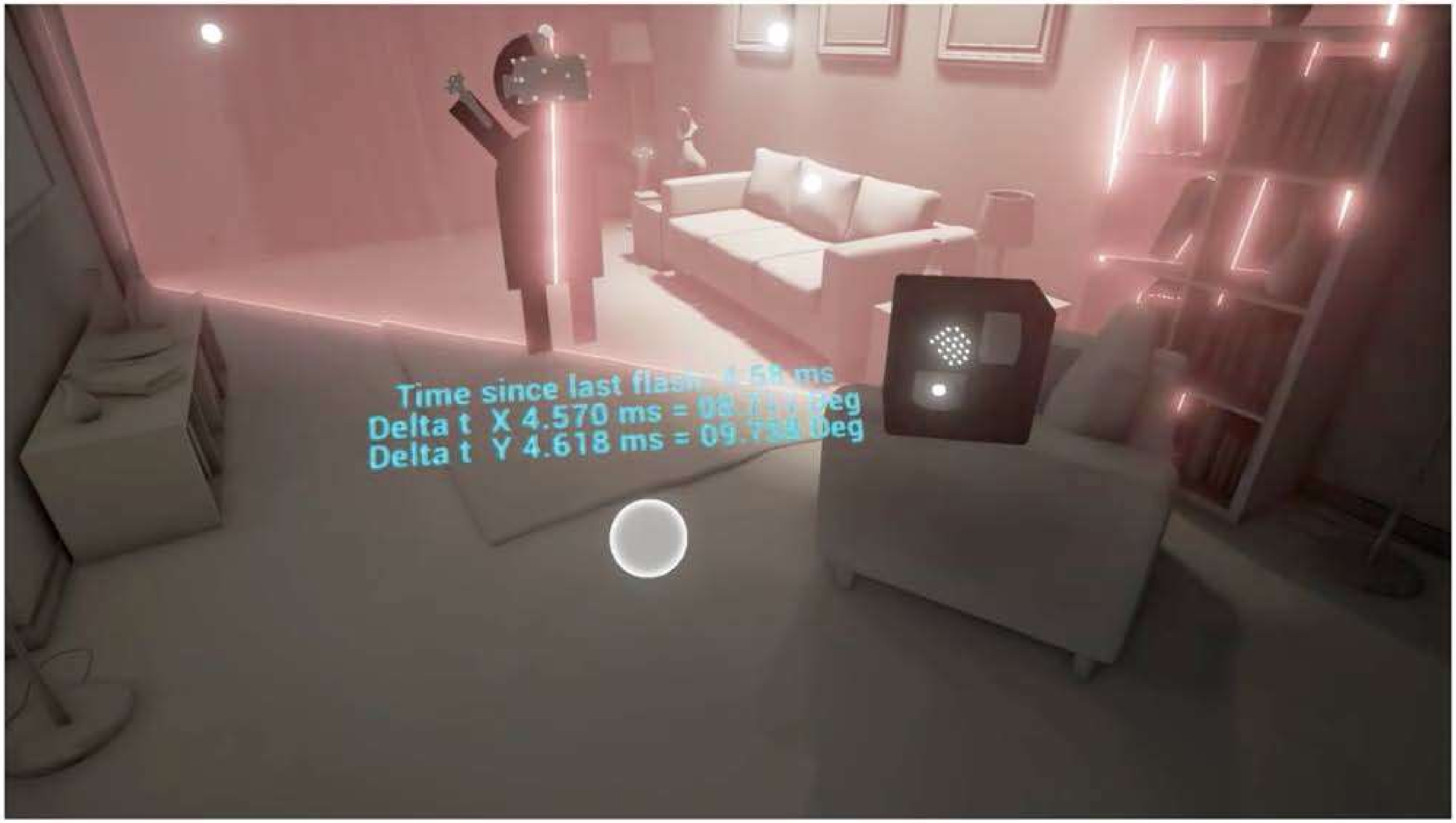
HTC Lighthouse





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

HTC Lighthouse



https://www.youtube.com/watch?v=J54dotTt7k0

HTC Lighthouse

important specs:

- runs at 60 Hz
  - i.e. horizontal & vertical update combined 60 Hz
  - broadband sync pulses in between each laser sweep (i.e. at 120 Hz)
- each laser rotates at 60 Hz, but offset in time
- useable field of view: 120 degrees
- sync pulse emitted 120 times per second
- each sync pulse indicates beginning of new sweep

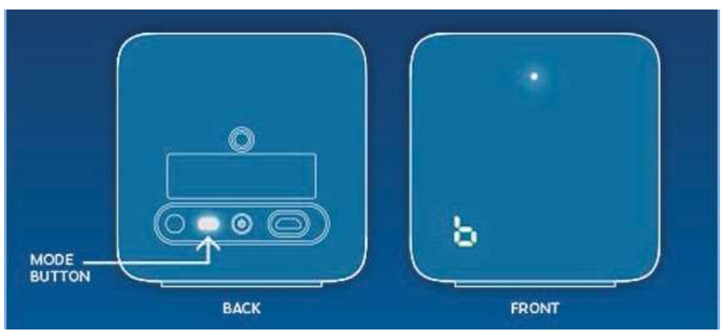
HTC Lighthouse – Base Station

- can use up to 2 base stations simultaneously via *time-division multiplexing* (TDM)
- base station modes:

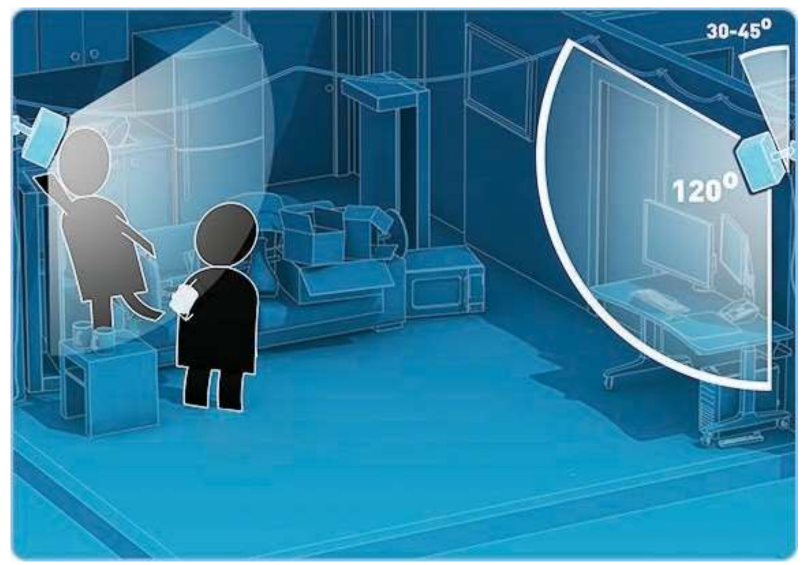
  A: TDM slave with cable sync

  B: TDM master

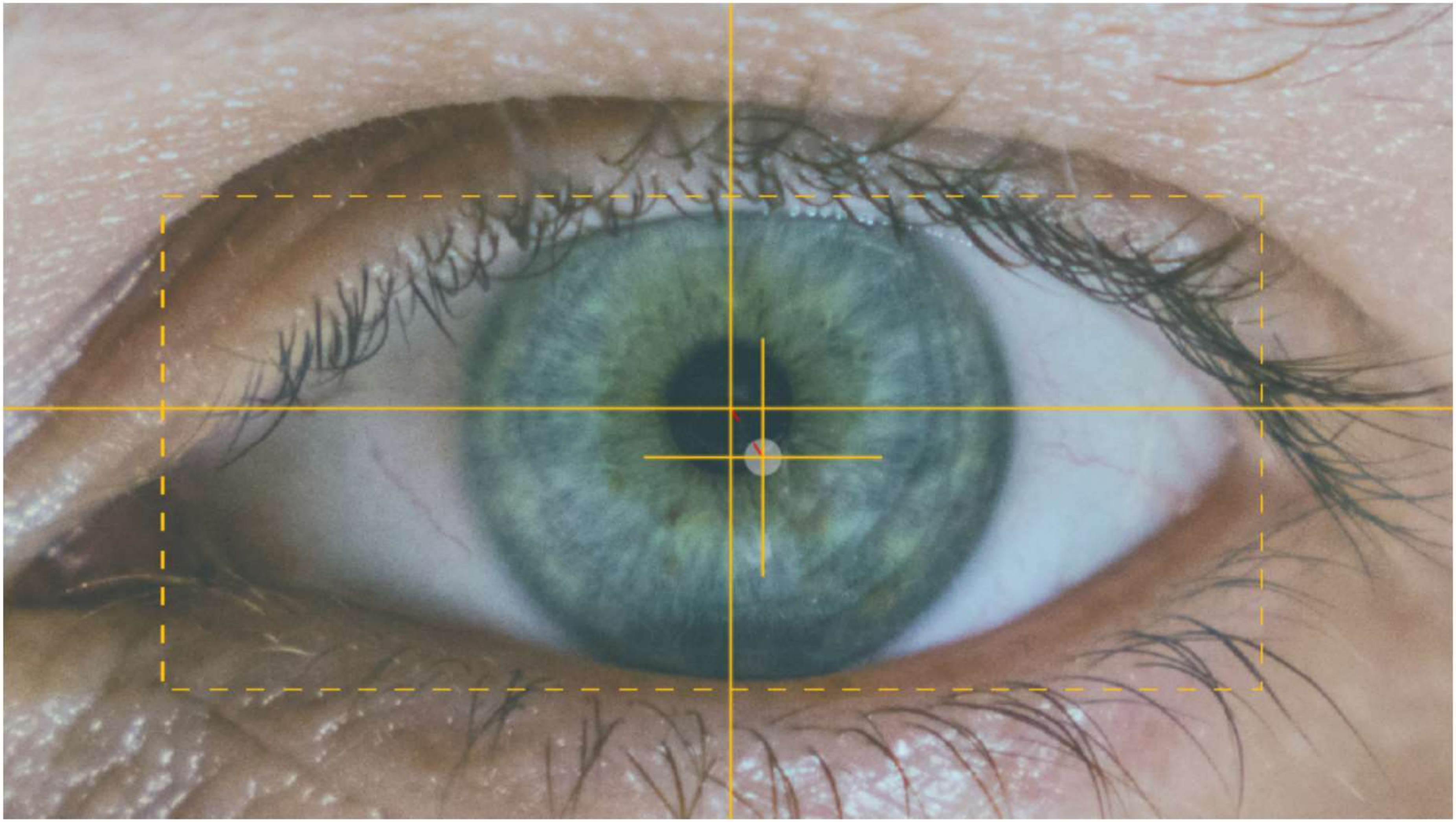
  C: TDM slave with optical sync



HTC



Eye Tracking



The center of the eye (pupil center) is tracked in relation to the position of the corneal reflection. The relative distance between the two areas allows the calculation of the direction of the gaze.

Tobii Eye Tracking

Add-on for VR headsets

Video: https://www.youtube.com/watch?v=q8GhIfsrizM

Vive Pro Eye

Vive Pro with built-in eye tracking

Separate product from regular Vive Pro

FOVE

Released Nov 2016

OLED display

2560×1440 pixels

70Hz refresh rate

90-100 degree field of view

6 DOF tracking with external camera

Eye Tracking: 120FPS infrared x2 (accuracy <1 degree)

Headphone jack (no built-in audio)

Eye Tracking Challenges

Pupil deforms during fast eye motion, inertia effects

Eye motion can be very fast

Small angular eye motion can mean large differences for distant objects