CSE 190: Virtual Reality Technologies

LECTURE #14: VR TRACKING

Announcements

Final Project on-line

- Due June 12th at 3pm
- Videos 3-4pm
- Presentations 4-6pm in two sessions

Two blog updates needed

- 2nd update due next Monday at noon

Video due June 12th at 12 noon

- Can be up to 3 minutes long
- Need to add to Youtube playlist

VR Club Project Showcase

I was wondering if you'd be able to advertise our Spring Project Showcase event to your students and project teams? This is the big final presentation where all our teams will be showing their work from the past 2-3 quarters, and we want it to be a big and exciting event! Here are the details:

Name: VR Club Spring Project Showcase
Date: Friday, June 8
Time: 2:00pm - 6:00pm (show up any time!)
Location: PC East Ballroom
This event is science-fair style, so attendees are welcome to arrive and leave at any time during the event to walk around and look at projects. We'll also have free Jamba Juice there!

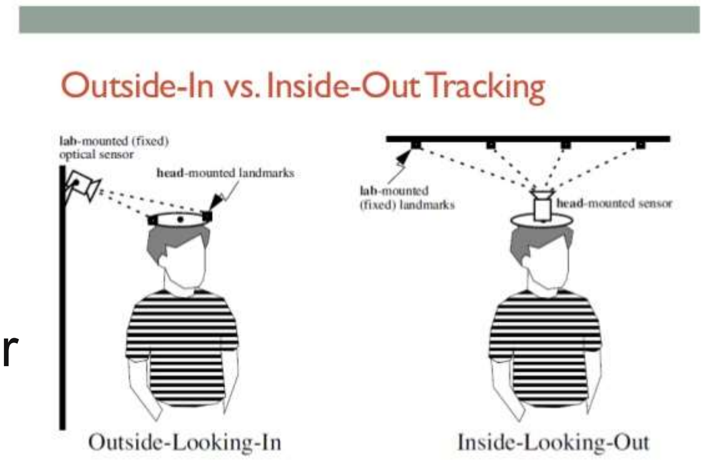
Types of Positional Tracking

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

- Used by most VR headsets today

"**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, Intel Project Alloy, Qualcomm VR820

Eventually required by all untethered VR/AR systems

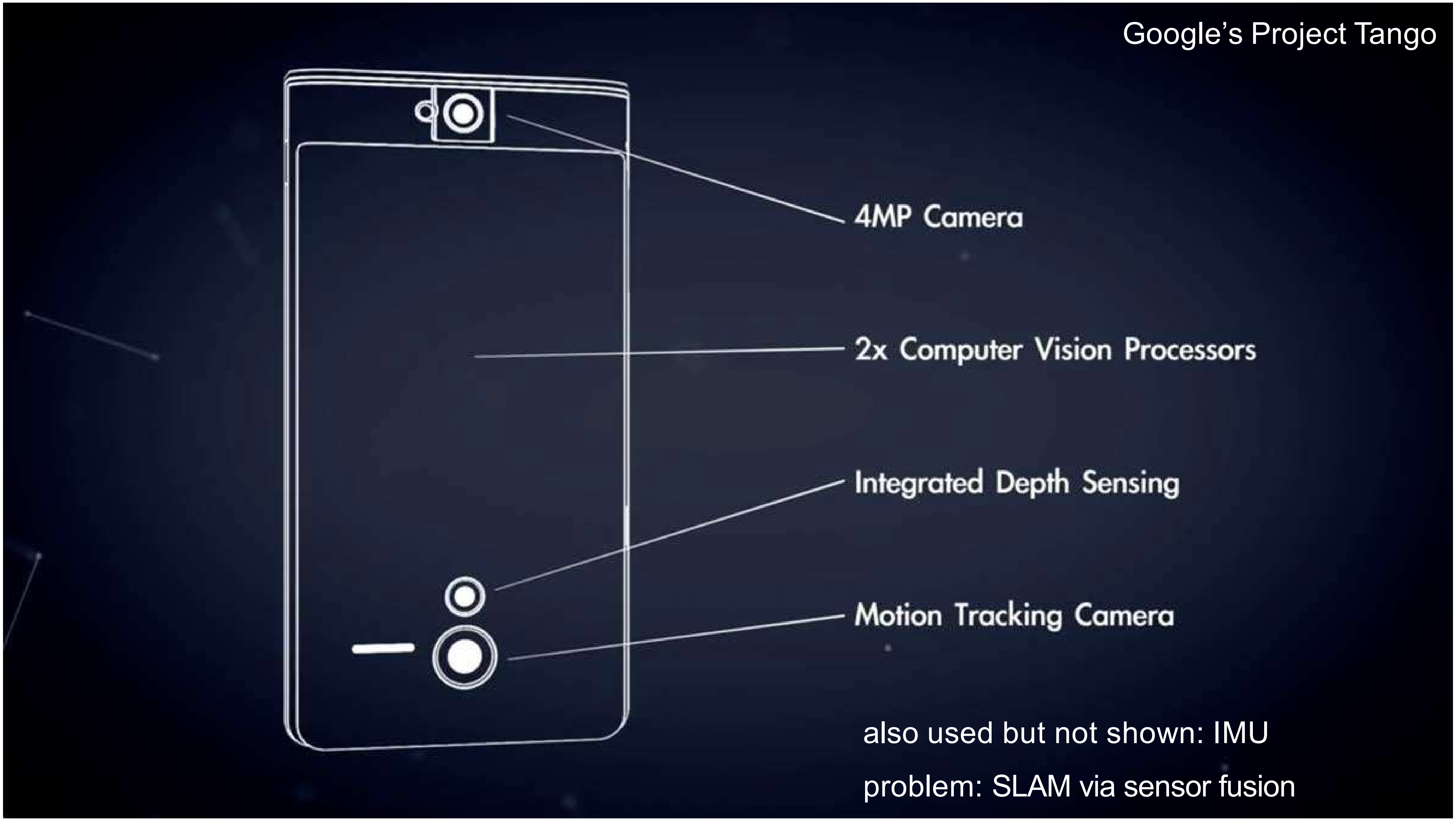
Lenovo Mixed Reality

Oculus Prototype

Inside-out Tracking

Google's Project Tango

Google’s Project Tango



also used but not shown: IMU

problem: SLAM via sensor fusion

Outside-in Tracking

mechanical tracking

ultra-sonic tracking

magnetic tracking

optical tracking

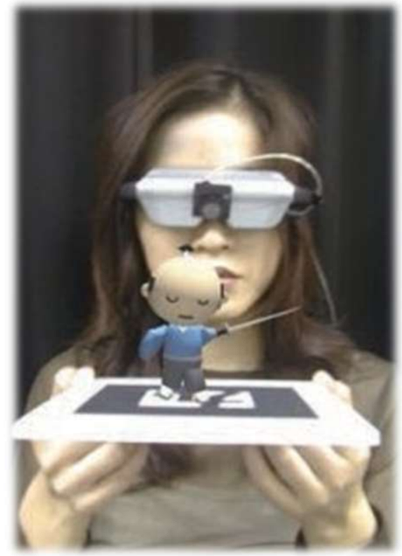
GPS

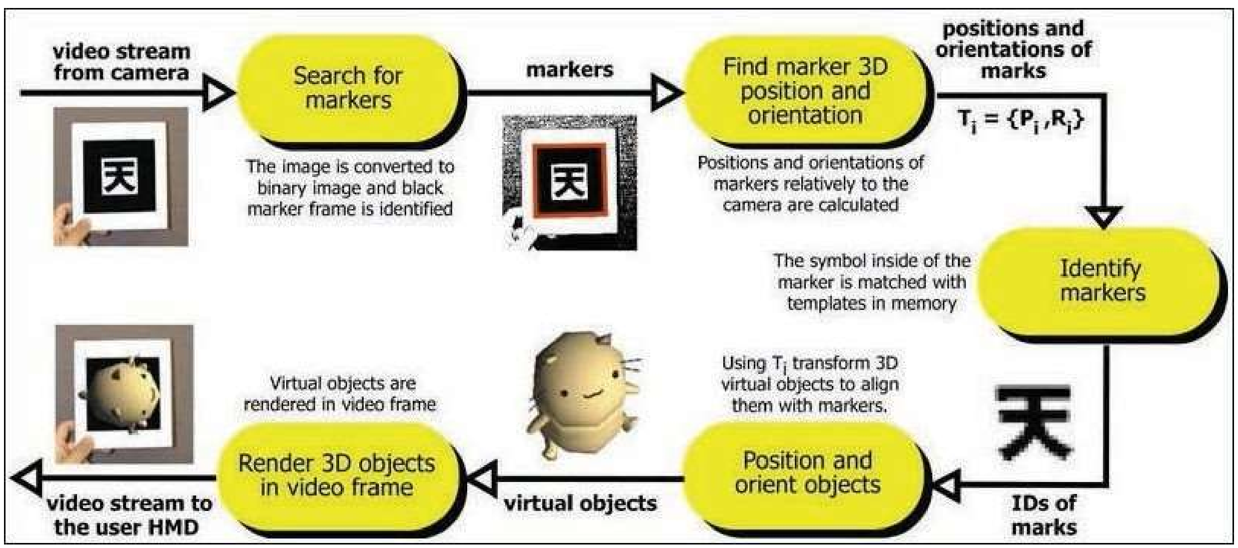
WiFi positioning

marker tracking

Marker-based Tracking

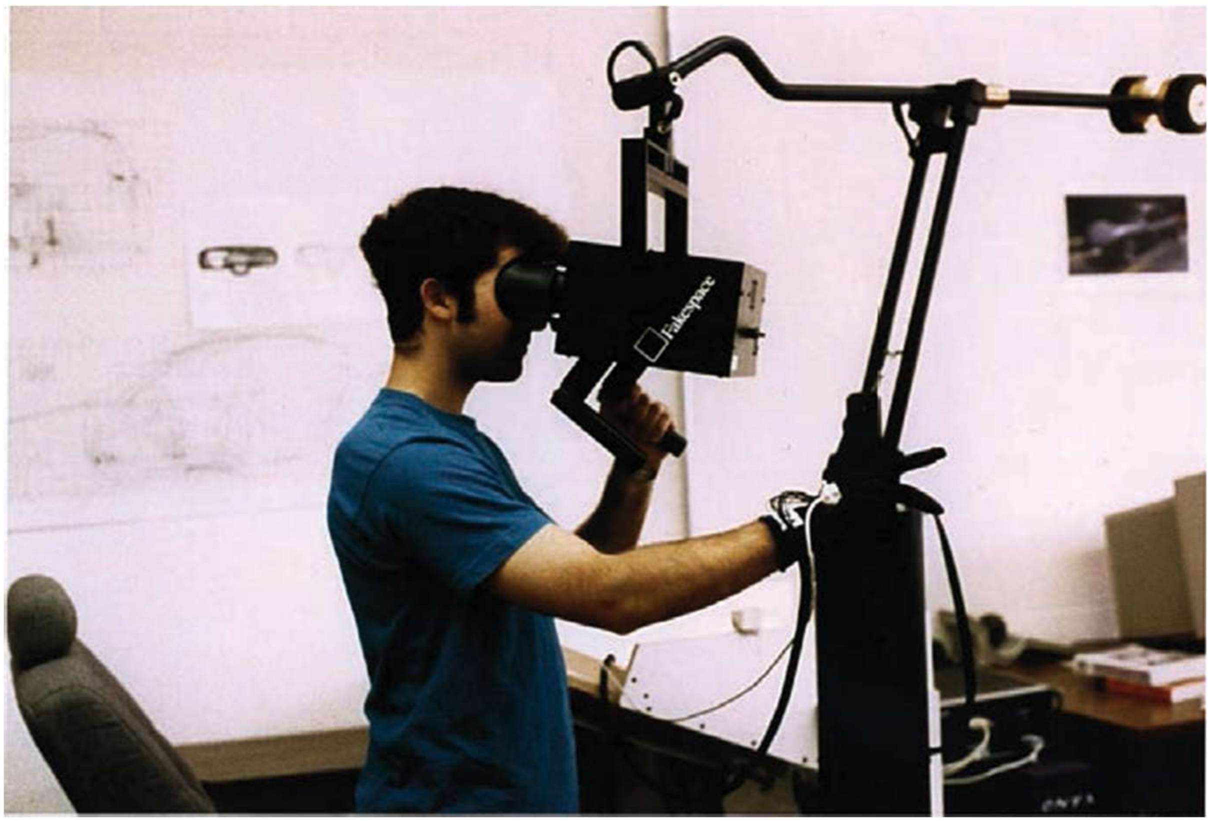
- Seminal papers by Rekimoto 1998 and Kato & Billinghurst 1999
- Widely adopted after introduction by ARToolKit





Kato, Billinghurst - ARToolKit

Positional Tracking - Mechanical



some mechanical linkage, e.g.

- fakespace BOOM
- microscribe

Positional Tracking - Mechanical

pros:

- super low latency
- very accurate

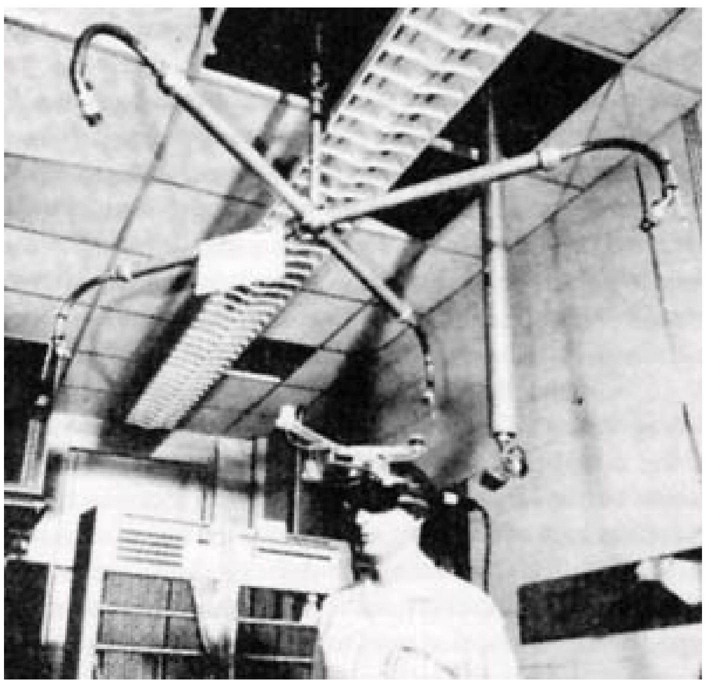
cons:

- cumbersome
- “wired” by design

Positional Tracking – Ultra-sonic

- 1 transmitter, 3 receivers ! triangulation

Ivan Sutherland's "Ultimate Display"



Logitech 6DOF

Positional Tracking – Ultra-sonic

pros:

- can be light, small, inexpensive

cons:

- line-of-sight constraints
- susceptible to acoustic interference
- low update rates

Positional Tracking - Magnetic

- reasonably good accuracy
- position and orientation
- 3 axis magnetometer in sensors,
- need magnetic field generator,
  e.g. Helmholtz coil
- magnetic field has to oscillate and be synchronized with magnetometers

3 axis Helmholtz coil
www.directvacuum.com

Positional Tracking - Magnetic

pros:

- small, low cost, low latency sensors
- no line-of-sight constraints

cons:

- Somewhat small working volume
- Susceptible to distortions of magnetic field
- Hard to do untethered (need to sync)

3 axis Helmholtz coil
www.directvacuum.com

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

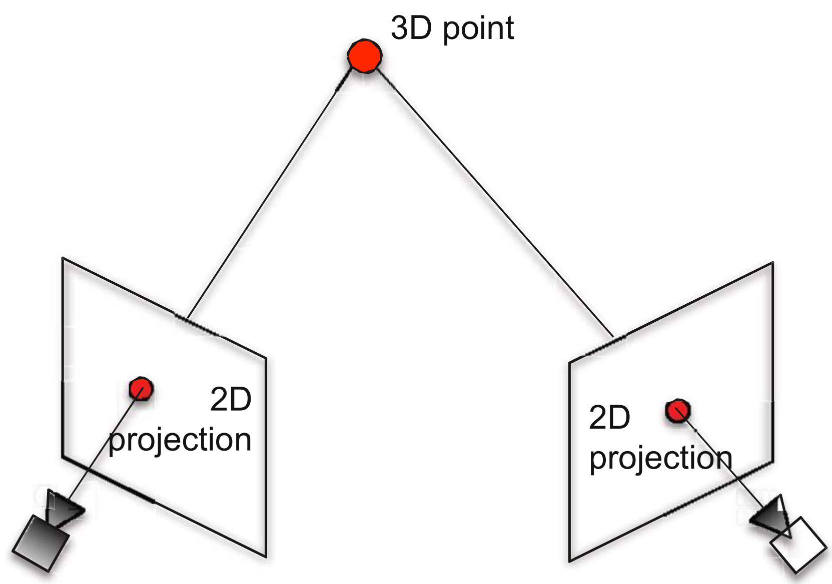
Oculus Rift
https://www.ifixit.com/Teardown/Oculus+Rift
+CV1+Teardown/60612

http://steam3.com/make-magic-2015/

Positional Tracking - Optical

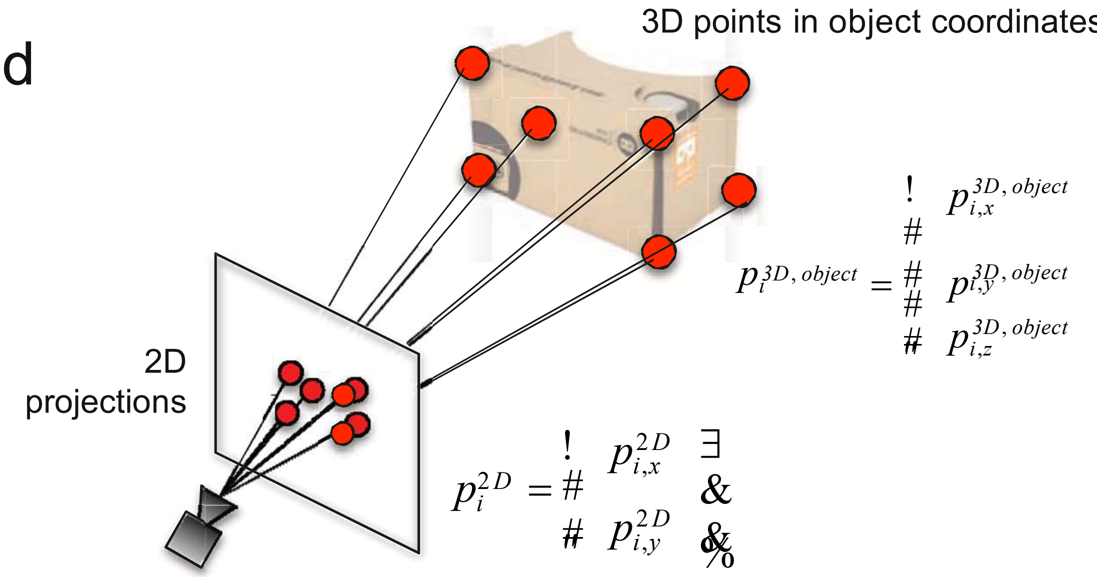
- for tracking individual 3D points, multi-camera setups usually use <u>triangulation</u>

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



Positional Tracking - Optical

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

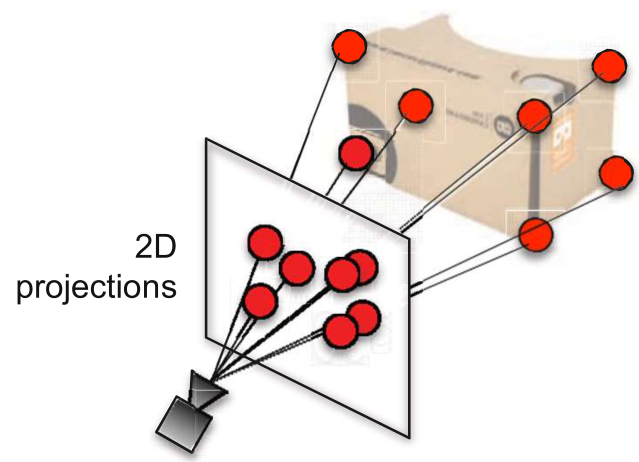


$$p_i^{3D,object} = \begin{pmatrix} p_{i,x}^{3D,object} \\ p_{i,y}^{3D,object} \\ p_{i,z}^{3D,object} \end{pmatrix}$$

$$p_i^{2D} = \begin{pmatrix} p_{i,x}^{2D} \\ p_{i,y}^{2D} \end{pmatrix}$$

Positional Tracking - Optical

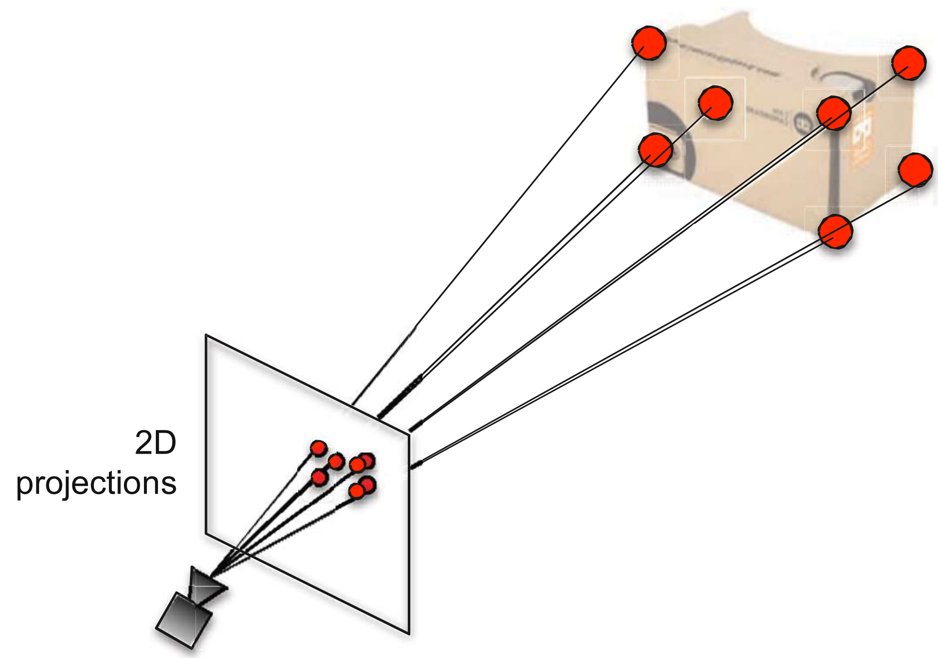
- when object is closer, projection is bigger



Positional Tracking - Optical

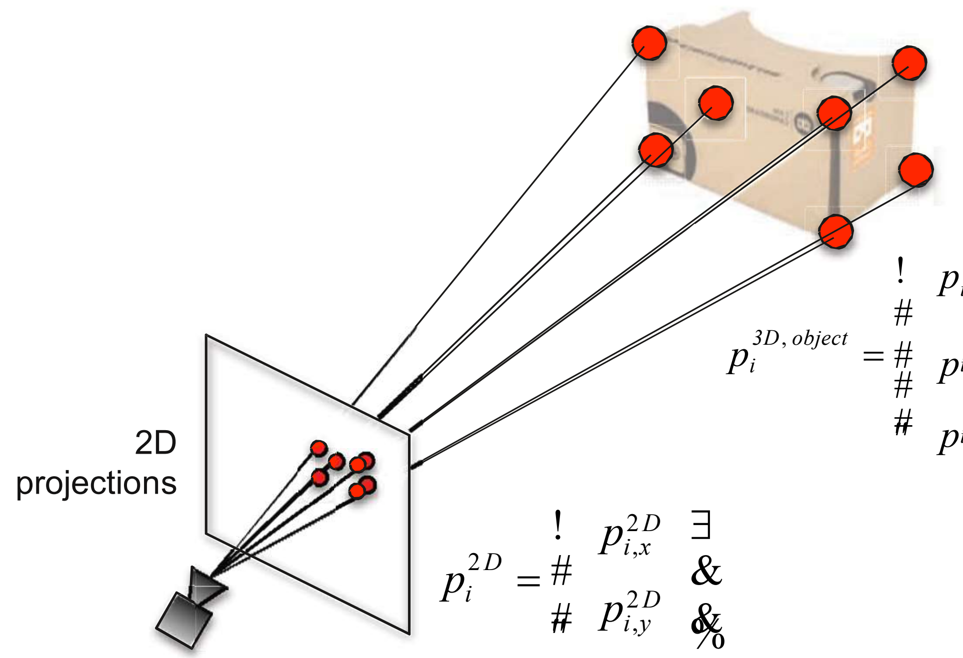
- when object is father, projection is smaller

... and so on ...



Positional Tracking - Optical

- pose estimation via optimization!
- nonlinear least squares problem



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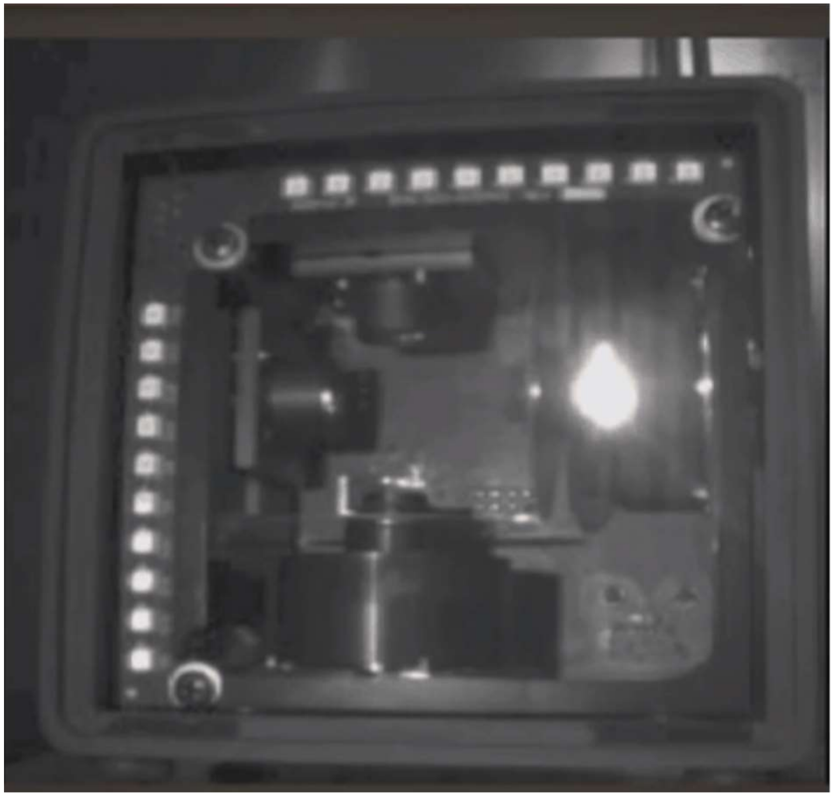
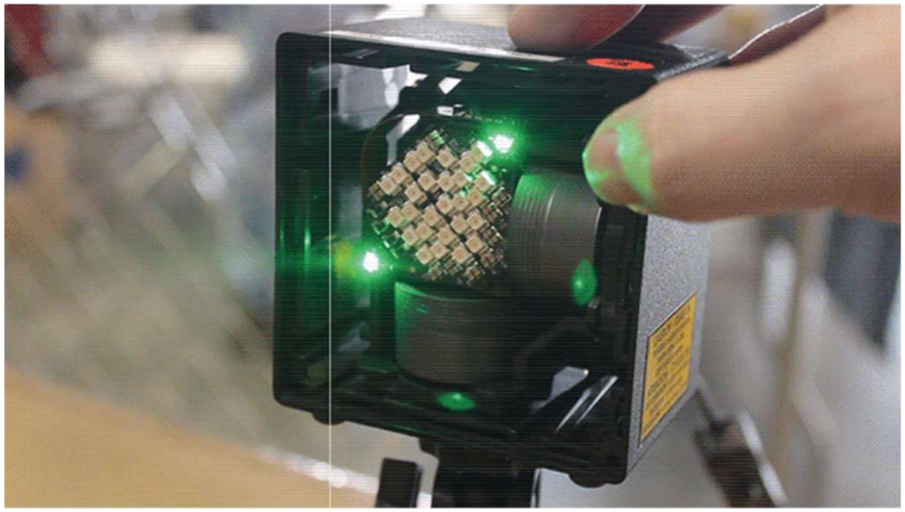
$$p_i^{2D} = \begin{pmatrix} p_{i,x}^{2D} \\ p_{i,y}^{2D} \end{pmatrix}$$

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

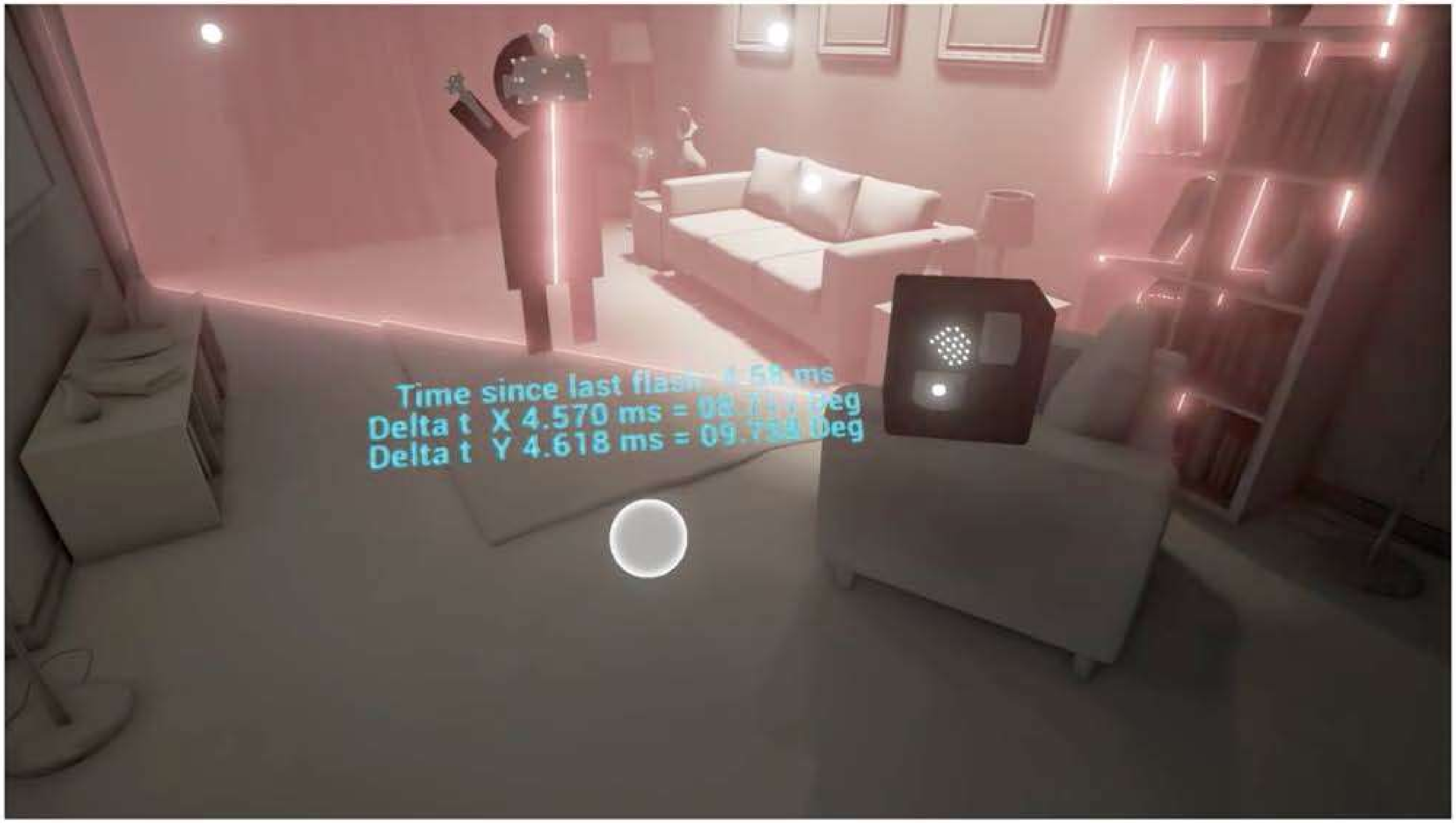
HTC Lighthouse





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

HTC Lighthouse



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

HTC Lighthouse

<u>important specs</u>:

- 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

HTC Lighthouse – Base Station

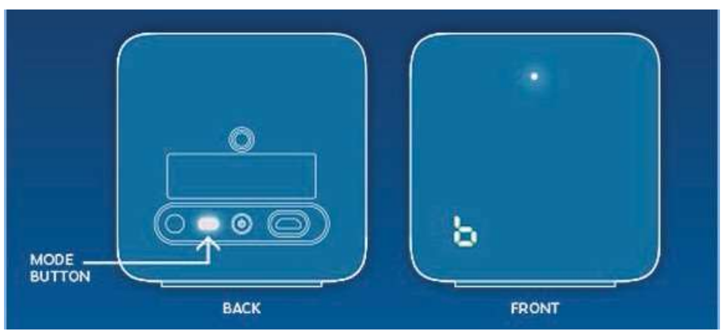
- can use up to 2 base stations simultaneously via *time-division multiplexing* (TDM)
- base station modes:

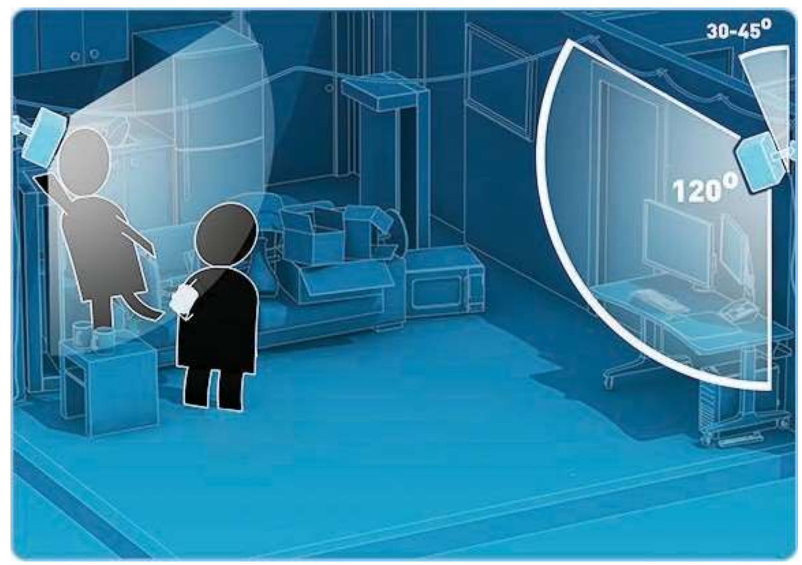
  A: TDM slave with cable sync

  B: TDM master

  C: TDM slave with optical sync

HTC





HTC Lighthouse – Base Station

- sync pulse periodically emitted (120 times per second)
- each sync pulse indicates beginning of new sweep
- length of pulse also encodes additional 3 bits of information:

Name	skip	data	axis	length (ticks)	length (µs)
j0	0	0	0	3000	62.5
k0	0	0	1	3500	72.9
j1	0	1	0	4000	83.3
k1	0	1	1	4500	93.8
j2	1	0	0	5000	104
k2	1	0	1	5500	115
j3	1	1	0	6000	125
k3	1	1	1	6500	135

- axis: horizontal or vertical sweep to follow
- skip: if 1, then laser is off for following sweep
- data: data bits of consecutive pulses yield OOTX frame

https://github.com/nairol/LighthouseRedox/blob/master/docs/Light%20Emissions.md#sync-pulse

HTC Lighthouse – Base Station

- OOTX frame used to communicate between base stations or with sensors
- can send calibration data and all kinds of info
- detailed info here: https://github.com/nairol/LighthouseRedox/blob/master/docs/Light%20Emissions.md#sync-pulse