CSE 190: Virtual Reality Technologies

LECTURE #11: 3D TRACKING TECHNOLOGIES

Announcements

Project 2 due Sunday May 10th at 11:59pm

Project 3 to be released Monday at 1pm during discussion

Smartphone AR survey

Midterm feedback survey

Cloud Mac: has anyone tried it yet?

Today's VR app presentations:

- Yichen Zhang: Raw Data
- Jeremy Lin: flyingshapes
- Anthony Tran: Provata VR

Overview

Position/Orientation Tracking
- Mechanical Tracking
- Electromagnetic Tracking
- Ultrasonic Tracking
- Inertial Tracking
- Optical Tracking
- Tracking with Radar

Outside-in/Inside-out Tracking

Hand/Finger Tracking

Eye Tracking

Application-specific Input Devices

Mechanical Tracking

Mechanical Tracking

Dependent on a physical link between a fixed reference point and the target

Example: BOOM display

- A HMD is attached on the rear of a mechanical arm with multiple points of articulation
- Detection of orientation and position is done through the arm

High tracking update rate

Limited range of motion for the user

Electromagnetic Tracking

Electromagnetic Tracking

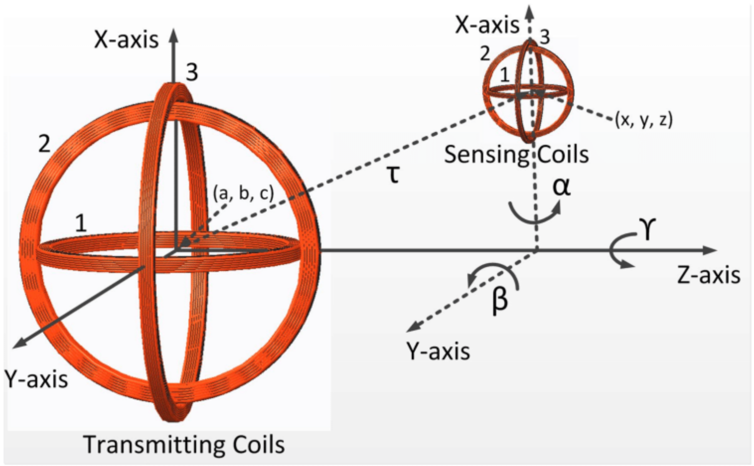
First used by military and in medical and animation industries

Concept:

- Fixed transmitter generates low-level magnetic field from 3 orthogonal coils
- Fields generate current in smaller receiver unit(s) worn by user
- 6-DOF tracking achieved by analyzing signal strength in receiving coils

Advantage: no line of sight restrictions

Disadvantage: metal in environment can cause interference



Electromagnetic Tracking

There are three pulses of about 2ms each.

The three pulses correspond to each of the three crossed coils in the base – they are pulsed in series.

The receiver coils in the tracked device receive each of the pulses with different amplitudes, depending on the relative orientation of the receiving and transmitting coils.

If their axes are aligned, the corresponding signal is strong. If they are not aligned, the signal is weaker, being weakest when the axes are perpendicular.

Changing the distance of the controller from the base changes the amplitude of all three signals in the same way.

From this information the computer can determine orientation and position of the tracked device.

One of the Earliest VR Tracking Technologies

1990 Ascention Flock of Birds

2011 Razer Hydra

2018 Magic Leap One

Flock of Birds

Magic Leap One

Razer Hydra

Magic Leap


Magic Leap One

Uses electromagnetic tracking to track controller’s position and orientation.

Electromagnetic signal emitter is in controller.

Receiver in on right side of headset. Tracking will probably be worse for left-handed use.

Copper shielding sprayed into the coil housings protects from RF interference, while letting the magnetic field through.

Interference could explain the tracker's placement outside of frame.


Receiver


Emitter

Ultrasonic Tracking

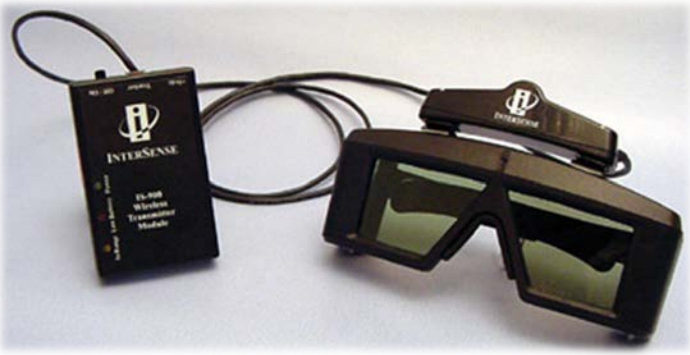
Ultrasonic Tracking

Systems measure duration of an ultrasound signal to reach microphones.

InterSense system uses combination of ultrasound and gyroscope.

Problems with echos from walls, people, objects in tracking space.

Logitech 3D Mouse



InterSense IS-900 tracker

InterSense IS-900 Wand

Inertial Tracking

Inertial Tracking

Trackers use **miniature gyroscopes** to measure orientation changes: 3 DOF

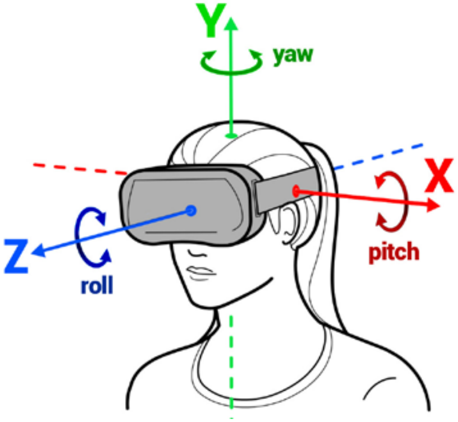
Accelerometers can help calibrate, add position tracking

Advantages:

- No external sensors needed
- Works outdoors
- No limitations on tracking space
- Cheap sensors mass manufactured for smartphones

Disadvantage: drift between actual and reported values, accumulates over time

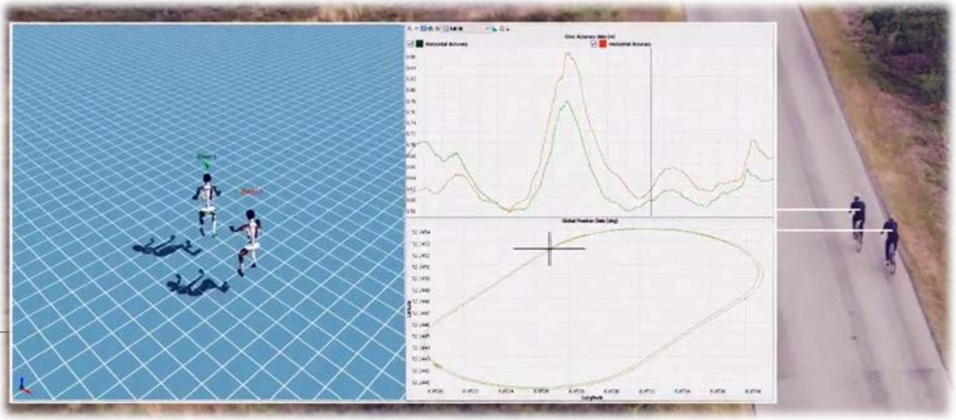
Gyroscope in Oculus Rift DK1

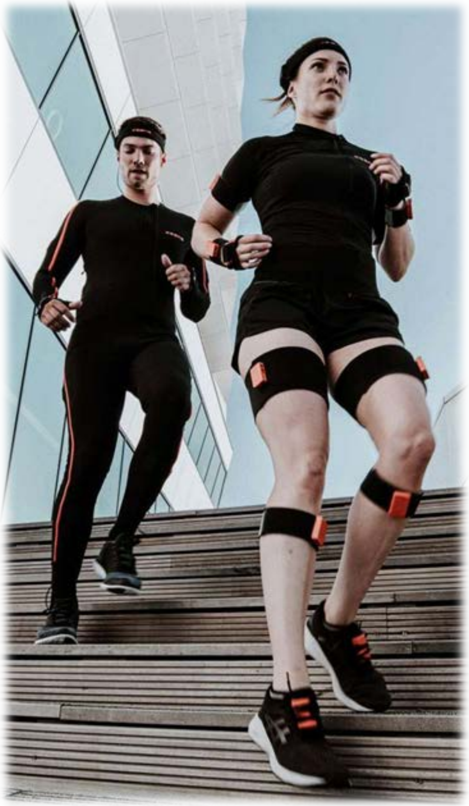


3 Rotational DOF

Xsens Motion Tracking

Long range motion tracking





Optical Tracking

Optical Tracking: HiBall

HiBall-3100 tracker system

Developed in 2001 at UNC Chapel Hill

System is composed of:

- HiBall Optical Sensor
  - Views infrared LEDs in beacon arrays on ceiling with 6 lenses and photodiodes
  - Ceiling beacon arrays

Tracker update rate: 2,000 Hz

No metal or sound interference

HiBall beacon array

Optical Tracking with Fiducial Markers

Printable markers placed in environment or on objects

A single camera can be sufficient

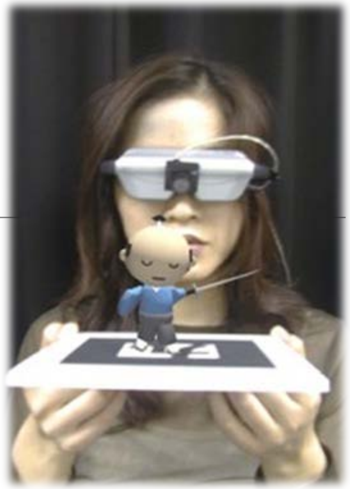
Flexible marker design: similar to QR codes

Markers cannot be rotationally symmetrical

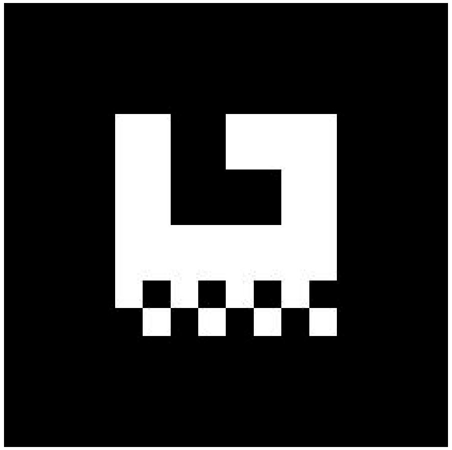
6 DOF tracking possible

PTC's Vuforia library allows any image or object to be a marker

- https://www.youtube.com/watch?v=ua9gRiHDHok



ARToolKit (2003)



ARToolKit marker

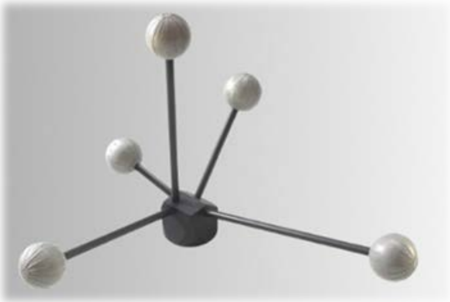
Optical Tracking with Marker Spheres

Available since 1990s

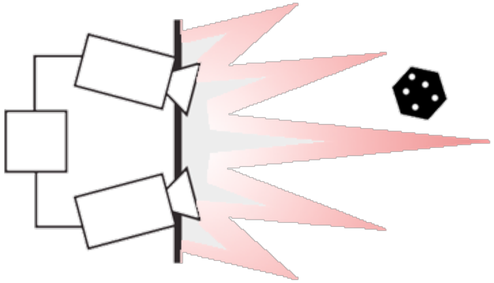
(Near-) Infrared light illuminates scene

Retro-reflective spheres reflect light back to the cameras

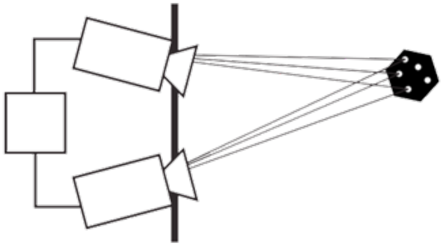
Spheres arranged in fixed, known configurations (constellations) allow for 6 DOF tracking



Marker constellation



The object is lit using near IR light



Retro-reflective markers reflect back

Motion Capture Suit

Optical Tracking with Infrared LEDs

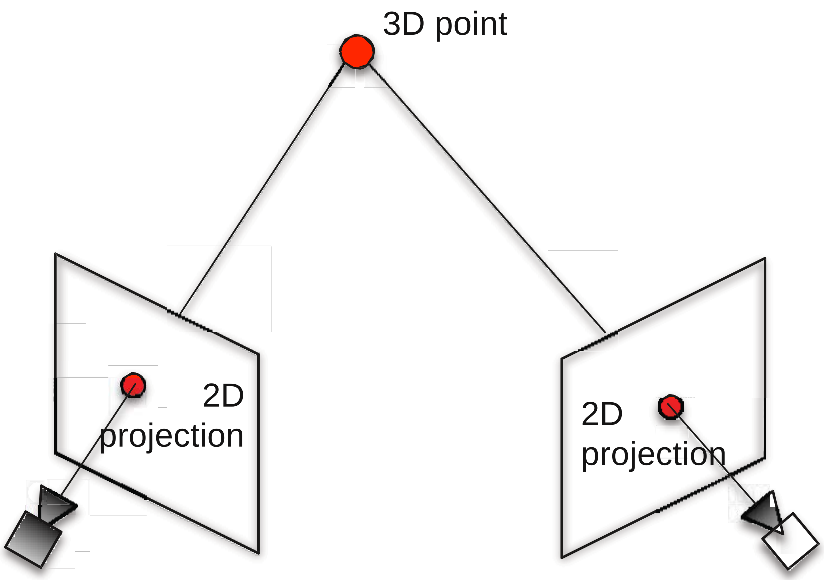
- Track active (near IR) LEDs with cameras
- Used on Oculus Rift

Oculus Rift CV1

Optical Positional Tracking

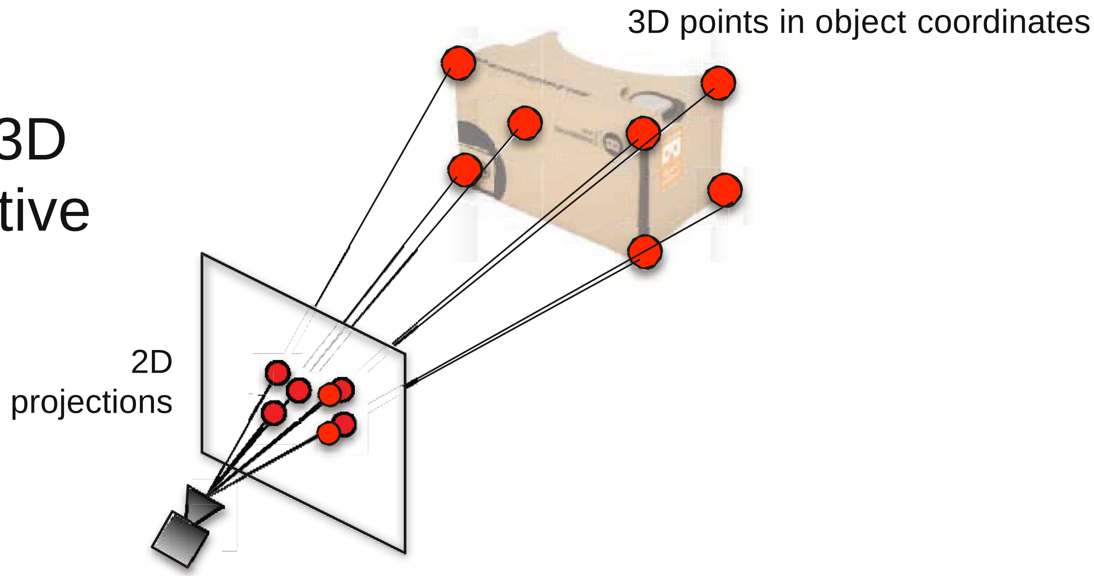
For tracking individual 3D points, multi-camera setups usually use triangulation

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



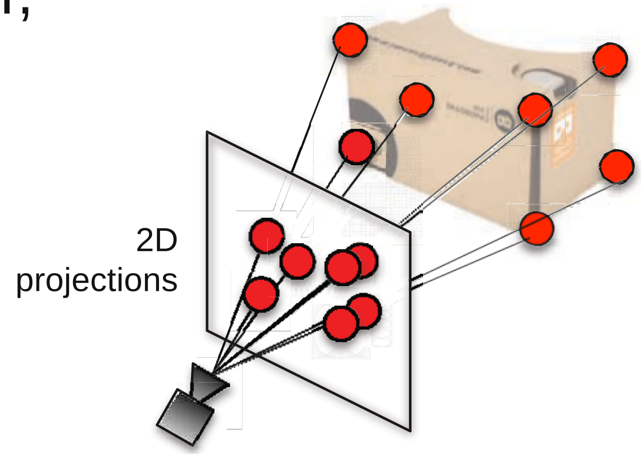
Optical Positional Tracking

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



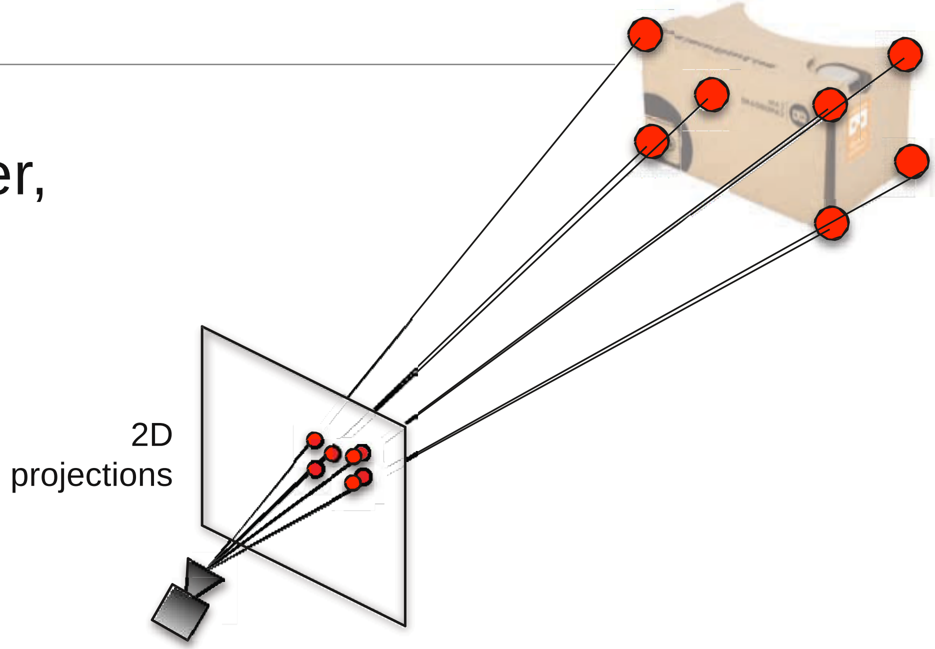
Optical Positional Tracking

When object is closer,
projection is bigger



Optical Positional Tracking

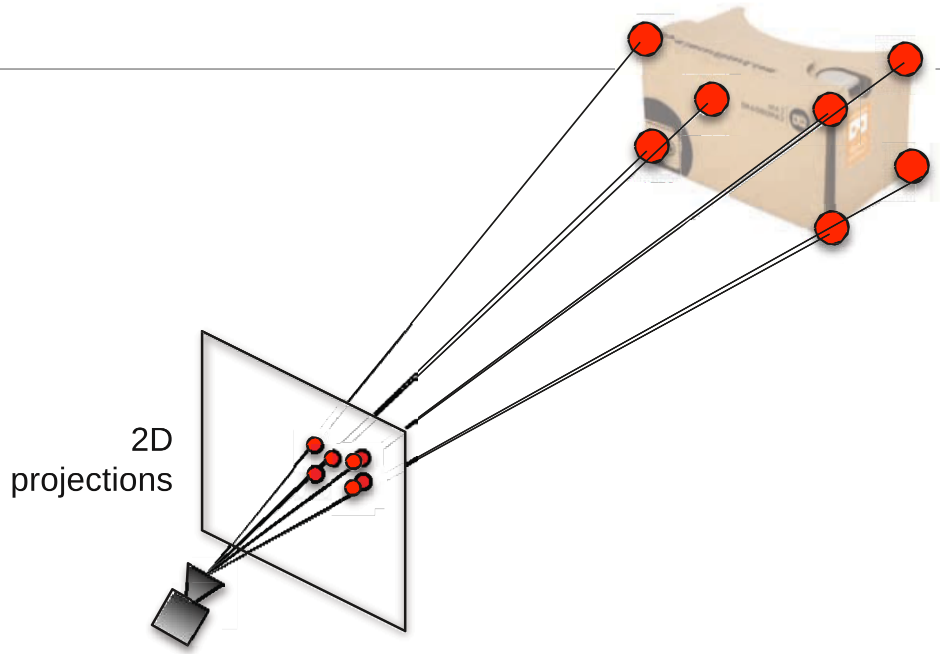
When object is father, projection is smaller



Optical Positional Tracking

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

Summary: Optical Tracking

Optical tracking works well for positional tracking (3 DOF)

Can provide full 6 DOF tracking with marker constellations