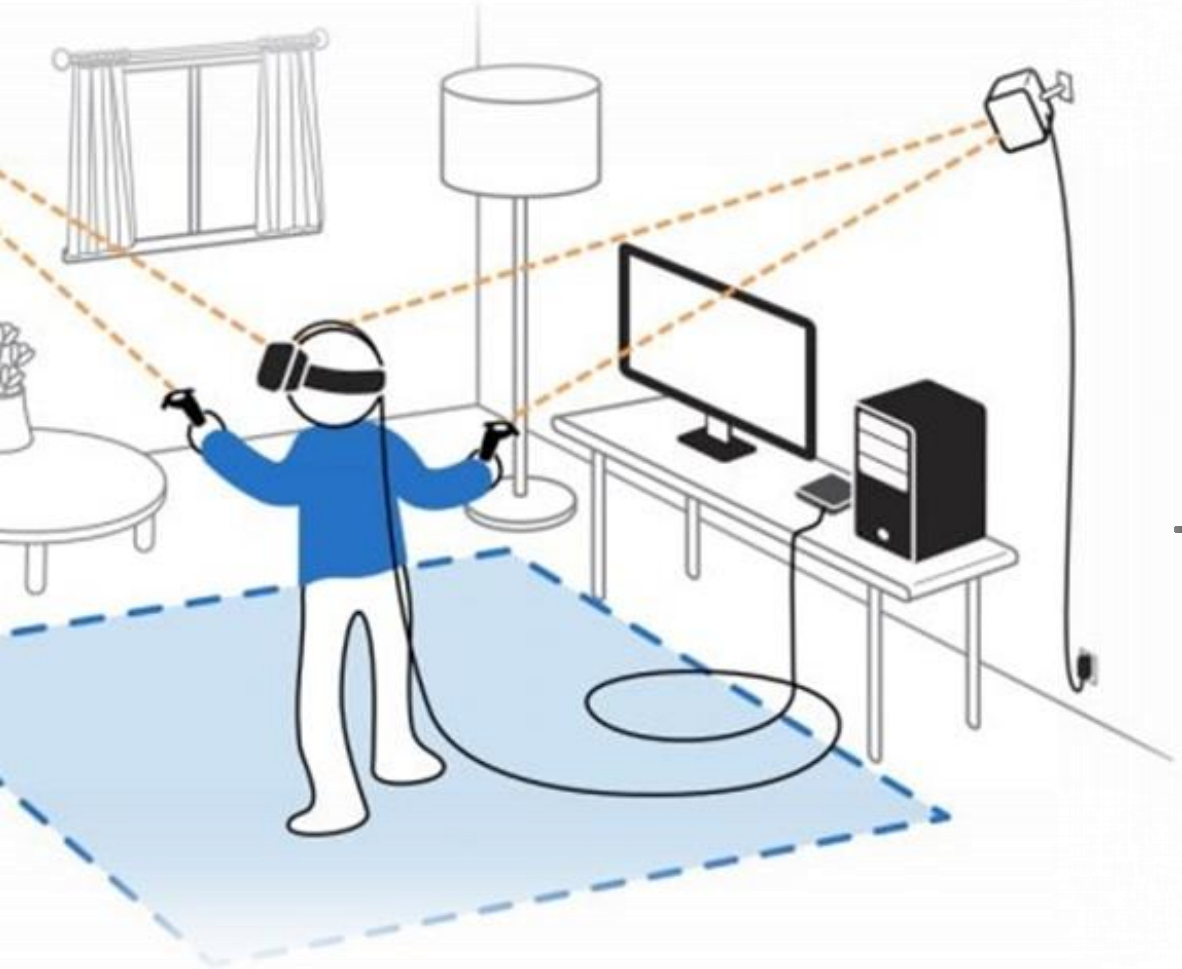
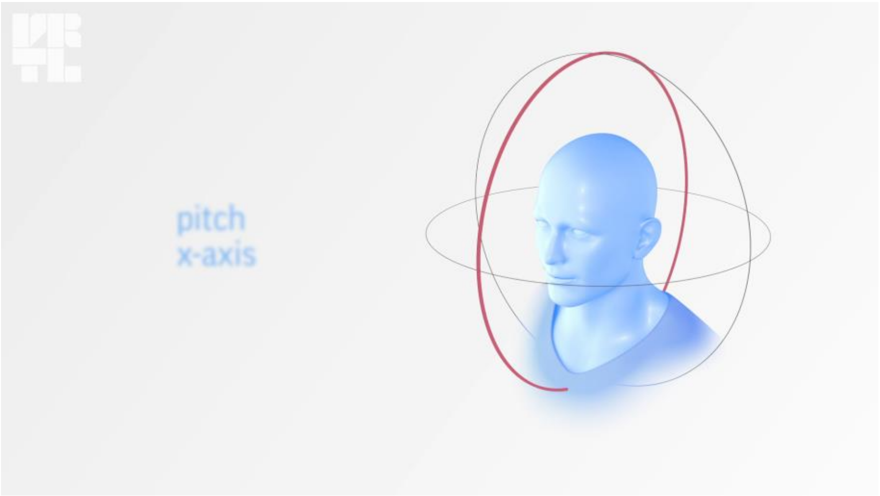


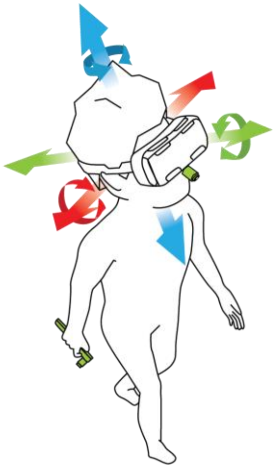
Tracking Systems II

Isayas Adhanom, Computer Science

Tracking in VR

- Track orientation and position of an object.
- Orientation tracking: rotational movements (yaw, pitch and roll)
- Positional tracking: translational movements (sway, heave and surge).



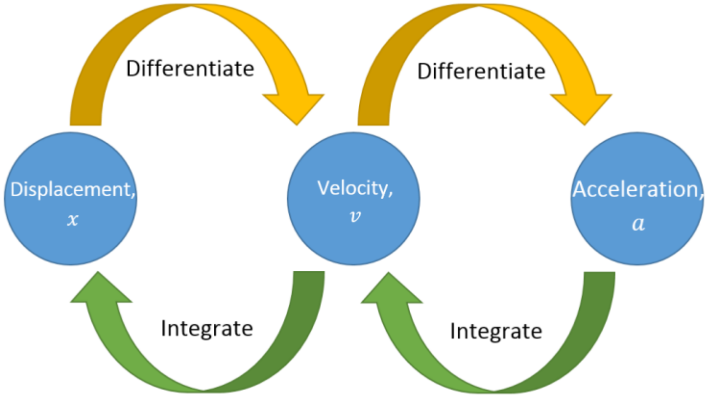


Tracking Position and Orientation

- Involves tracking all 6 DOFs for a moving rigid body.
- The position and orientation of a body is referred as it’s pose.
- The most important body to track in VR is the head.

Why not Just Integrate the Accelerometer?

- If gravity component is subtracted from accelerometer output, the remaining part is pure body acceleration.
- We can integrate acceleration twice to obtain displacement.
- What is the problem with this?
    - Drift error grows quadratically.



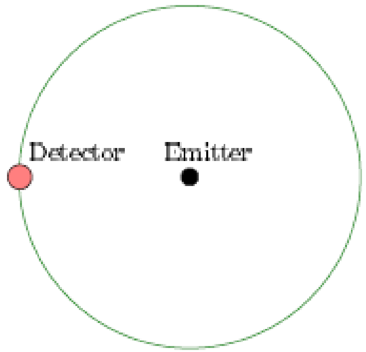
Why not Just Integrate the Accelerometer?

- Accelerometers can not accurately estimate acceleration when the sensor rotates quickly.
- Accelerometers can not distinguish motions with constant velocity.
- IMUs (gyroscope + accelerometer) play an important role in tracking but are not sufficient for positional tracking.

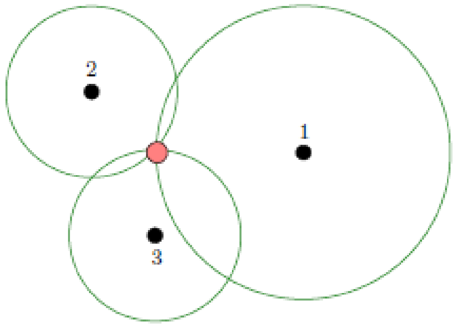
Make Your Own Waves (Active Approach)

- Take an active approach by transmitting waves into the environment.
- Waves perceptible by humans such as light and sound are not preferred.
- Non perceptible waves are preferred, eg: infrared, ultrasound, end electromagnetic fields.

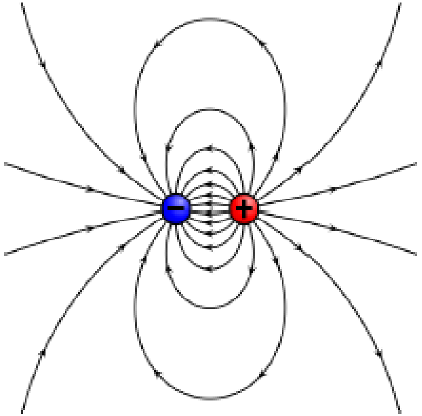
Make Your Own Waves: Ultrasound



- Consider using ultrasound pulse and an emitter-detector pair.
- Calculate time of arrival (TOA).
- Estimate distance based on the propagation speed of sound.
- With four more transmitters the position can be uniquely determined (trilateration).
- Drawback: Reverberations could cause the pulse to be received multiple times at each detector.



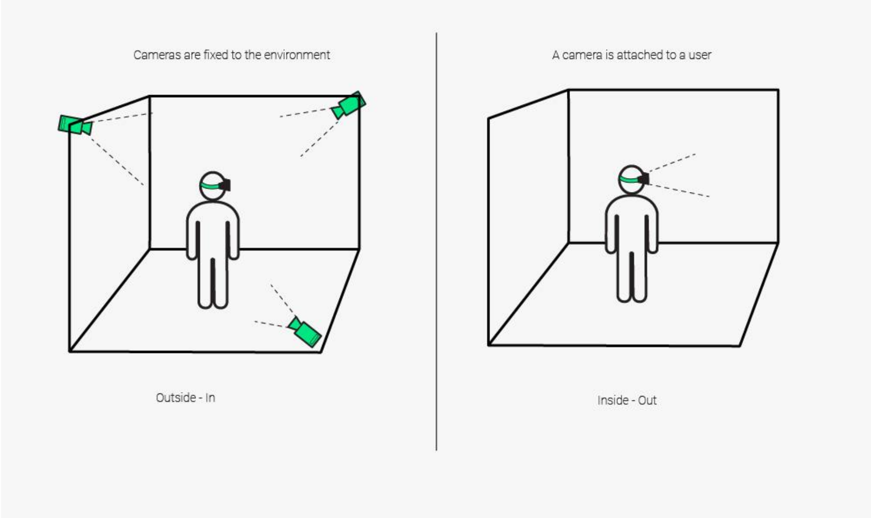
Make Your Own Waves: Magnetic Fields



- Emitting a complicated field that varies over the tracking area.
- The position and orientation of a body in the field could be estimated.
- Drawback: the field may become unpredictably warped.
- This could cause straight-line motions to be estimated as curved.

Line of Sight (Visibility) Methods

- Identify special parts of the physical world (features).
- Calculate the positions of the features along a LOS ray to a known location.
- Features should be distinguishable.
- Features could be natural/artificial.



Artificial Features

- Features are engineered and placed in the environment.

- They can be easily detected, matched to preassigned labels and tracked.

- Easy computer vision problem.

- We can use QR tags, retroreflective markers, LEDs …

Natural Features

- Features are automatically discovered, labeled and maintained during the tracking process.
- Remove moving objects from scene.
- This is a hard computer vision problem.
- It has low reliability.

Active Features

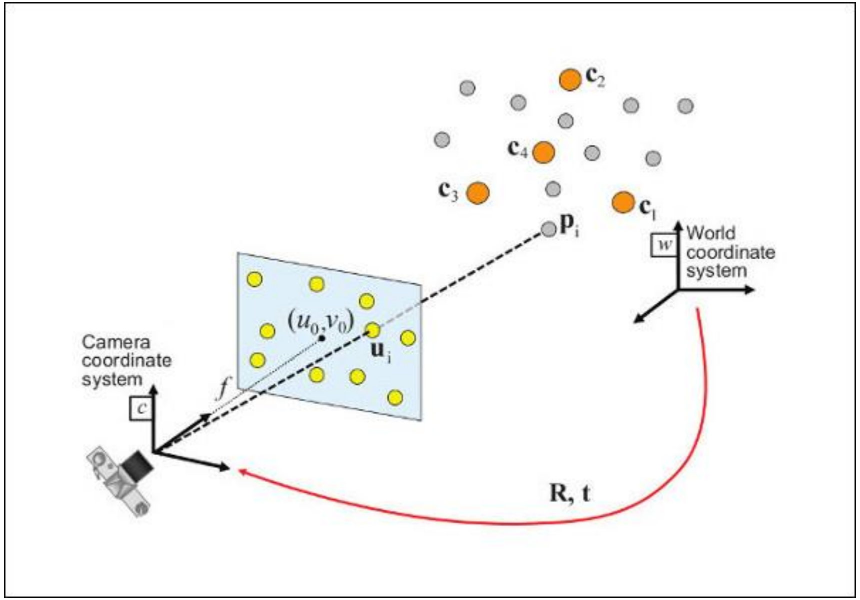
- We can also use active features that emit their own light.
- Colored LEDs can be mounted on the surface of a headset or controller.
- May require power source and increase cost and size of tracked object.

Using Infrared

- Visible to cameras but not to humans.
- IR LEDs can be mounted on devices (eg: Oculus Rift headset).
- Drawback: range is limited because IR must travel from camera to source and back.
- Why do we capture the whole scene?
- How can we conserve energy?
    - Use IR LED and detection photodiode.

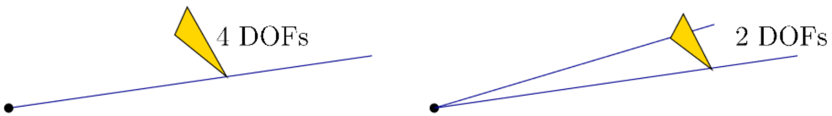
PnP Problem

- The problem of estimating the pose of a rigid body given a set of *n* 3D points in the world and their corresponding 2D projections in the image.



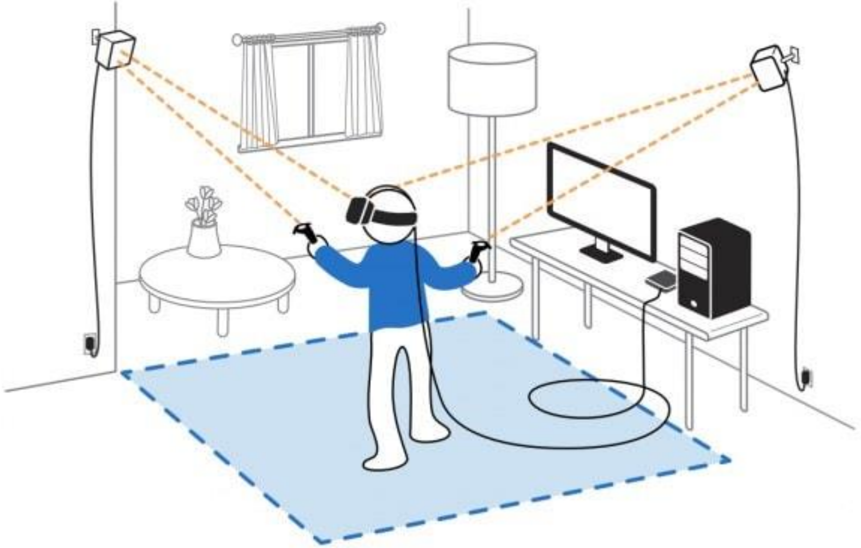
PnP Problem

- You can track 6 DoFs with 3 points.
- With 3 points (P3P) you end up with 4 possible positions.
- With 6 points (P6P), if no four features are co-planar, you can obtain unique solutions.
- The more points the better.

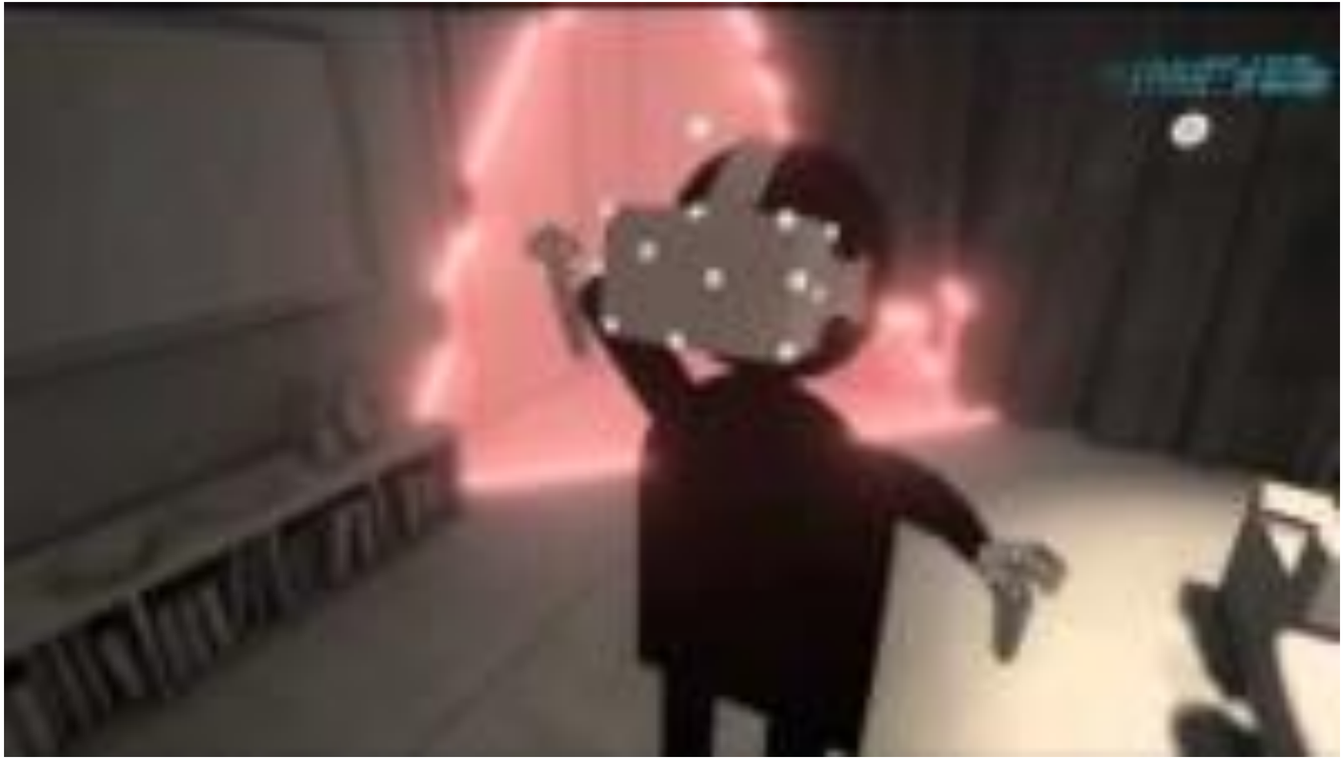


Light House Approach

- Consists of a special emitter-detector pair,
- Solves the visibility problem of camera based techniques.
- Uses lasers to sweep the environment horizontally and vertically.
- Video link



Light House Approach



Filtering

- We can use sensor fusion to use data from all sensors, including:
    - Gyroscope
    - Accelerometer
    - Magnetometer
    - Camera LED’s/Photodiodes
- Doubly integrate accelerometer data and correct drift using data from camera with a filter.
- We can use complementary filter, Kalman filter or Perceptually tuned gain.

Eye Tracking

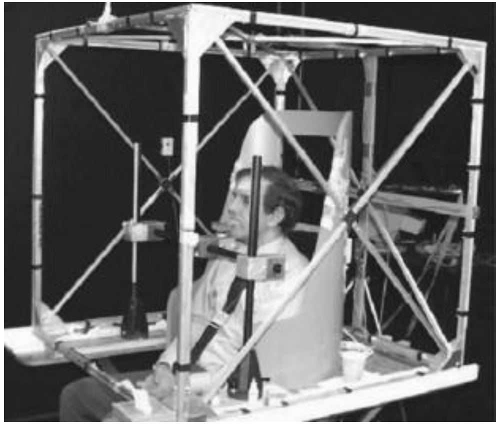
- Eye tracking has four main uses in VR:
  - To accomplish foveated rendering
  - To study human behavior
  - To improve social interaction in VR
  - To develop accessible interaction techniques

Electro-oculography

- Obtains measurements from electrodes placed on the skin around each eye.
- The recorded potentials correspond to eye muscle activity.
- Could detect movements even when eyes are closed.

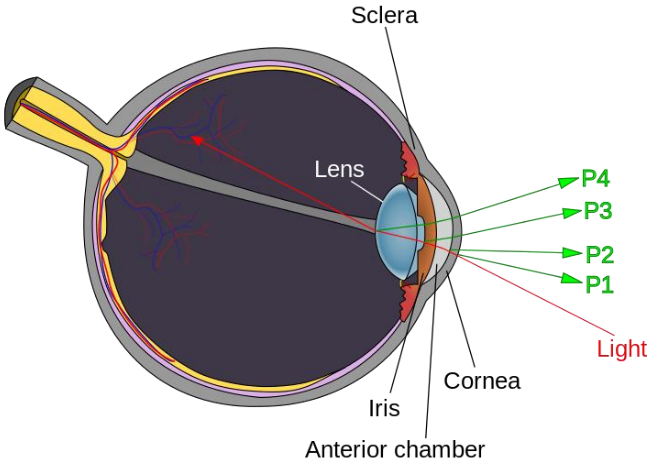
Scleral Search Coils

- A wire loop is placed on the sclera of the eye.
- The head is positioned between large Helmholtz coils.
- Most accurate form of eye tracking.
- Can achieve high sampling rate.



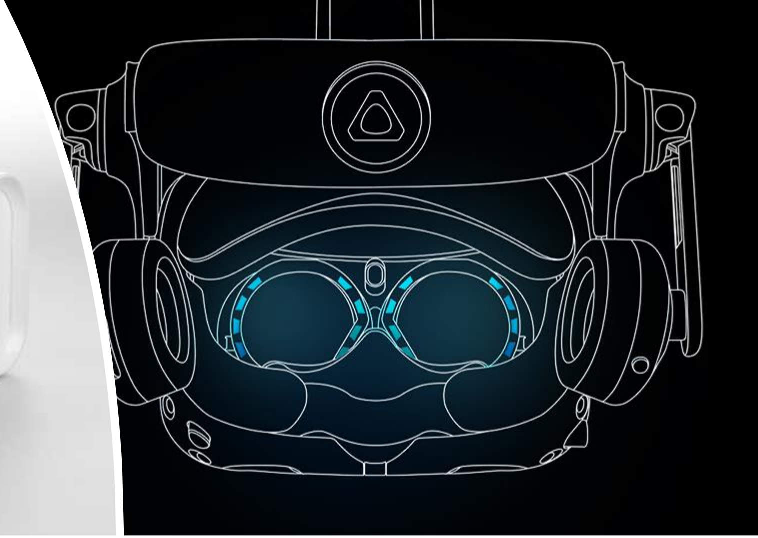
Video Oculography

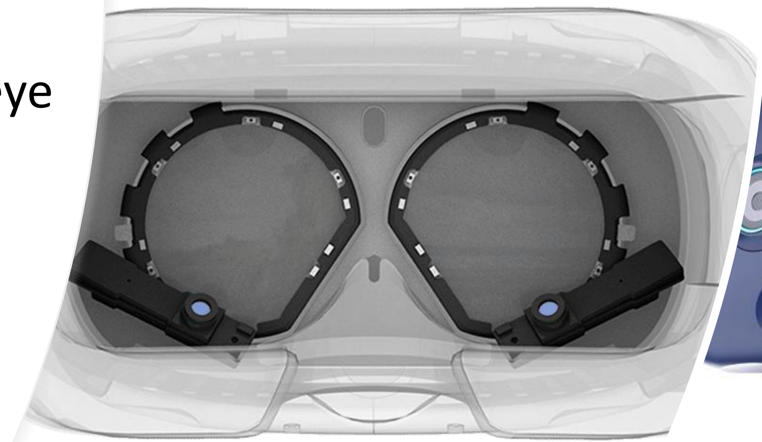
- Shine IR light onto the eye and sense it’s corneal reflection using a camera or photodiodes.
- The reflection is based on Purkinje images.
- This is low cost and minimally invasive.
- This is the most commonly used method today.



HMD Based Eye Trackers

- Eye trackers fitted inside VR HMDs.
- IR Based VOG eye trackers.



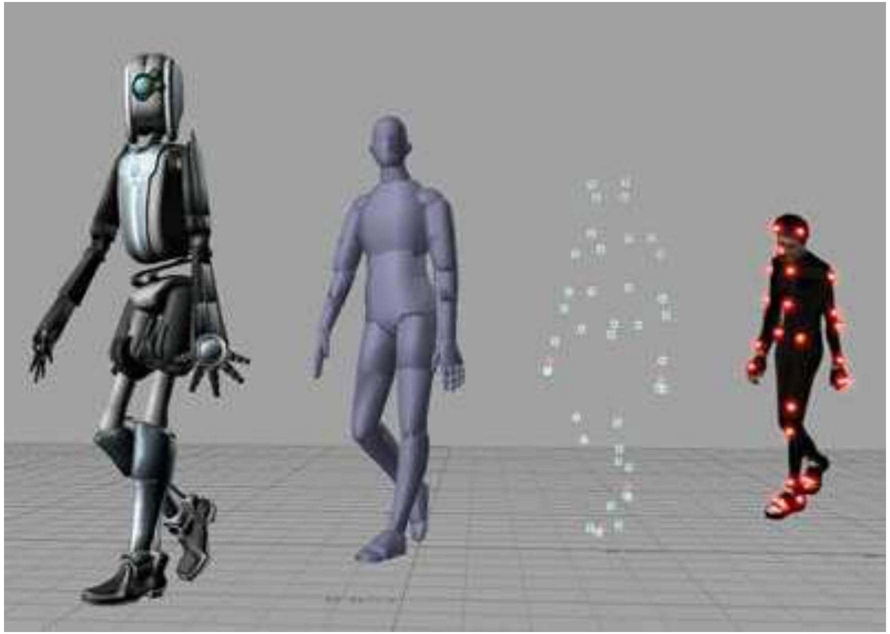


Tracking Attached Bodies

- Tracking systems for attached bodies use kinematic constraints to improve their accuracy.

- Determine the joint parameters for a chain of bodies by considering the constraints on the bodies.

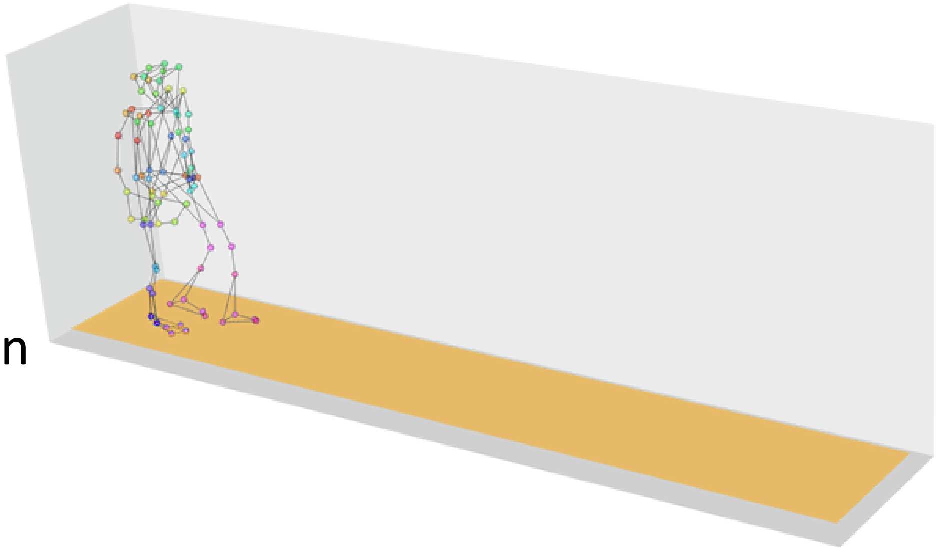
- Can use forward or reverse kinematics.



Motion Capture Systems

- Used to bring the motions of real actors are into a virtual world for animation.

- Use cameras with surrounding IR LEDs and retroreflective markers on the actor.



Motion Capture systems

3D Scanning of Environments

- Mapping - representation of the world for the purposes of navigation and collision avoidance.
- Localization – estimate location with in the world.
- Classical problem in robotics.
- We use SLAM (simultaneous localization and mapping)

Main Ingredients for 3D Model Building

1. Extracting 3D point cloud from a fixed location.
    - Using cameras and depth cues, or a camera and a laser.
2. Combining point clouds from multiple locations.
    - Stich (fuse) data from multiple sources while considering the sensors pose.
3. Converting a point cloud into a mesh of triangles