# Tracking for VR

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## Head Tracking: Definitions and Requirements

- Accuracy
  - The head tracking must be accurate in both position and orientation
- Low-Latency
  - Time from sampling head position to displaying the appropriate scene should be minimized.
- Update Rate
  - A low tracking update rate gives the impression of lag, making latency issues worse.
- Robustness
  - The head tracking must handle errors well by filling in values appropriately instead of causing the scene to jump or flash.
- Degrees of Freedom
  - Too small a field of view can give the impression of a "floating TV" instead of an immersive experience.

M. Malciu and F. Prêteux, A Robust Model-Based Approach for 3D Head Tracking in Video Sequences, Institut National des Télécommunications.
B. Lang, Datura Virtual Reality Setup using Sony HMZ-T1 HMD, Road to VR, 8 Aug 2012.

# Technologies for Head Tracking

- Mechanical
- Ultrasonic/Acoustic
- Electromagnetic
- Inertial
- Optical
- Hybrid

G. Baratoff and S.Blanksteen, *Tracking Devices*, Encyclopedia of Virtual Environments, 1993.

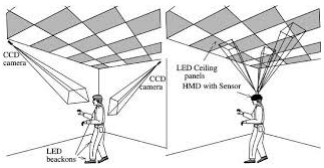
# Mechanical

Mechanical head tracking involves a mechanical arm that is attached to the user's head. The arm directly measures the motion of the user's head. It is a highly accurate and very quick way to measure head motion.

Sutherland: AFIPS Joint Computer Conference Archive (1968).

Y. Chow, 3D Spatial Interaction with the Wii Remote for Head-Mounted Display Virtual Reality, World Academy of Science, Engineering and Technology 50 2009.

# Optical




Two possibilities:

- Cameras are placed on the HMD and LEDs placed in known locations in the environment so that the movement of the head can be tracked with reference to the change of position of the LEDs in the video feed.
- A camera could also be placed in the environment and LEDs attached to the HMD. One variation on this set up uses one camera and one source of infrared radiation.

**+:** Easily scalable

**- :** Line of sight

A recent form of optical face tracking is taking video of the user and using face detection to determine the head's placement and orientation. It wasn't being used for AR or VR now, but as the HMDs become smaller it could become feasible.

Welch, Greg, Gary Bishop, Leandra Vicci, Stephen Brumback, Kurtis Keller, D'nardo Colucci. 1999. "**The HiBall Tracker: High-Performance Wide-Area Tracking for Virtual and Augmented Environments**," Proceedngs of the ACM Symposium on Virtual Reality Software and Technology 1999 (VRST 99), University College London, December 20-22, 1999. *Best paper* award.

R. Tomari, Y. Kobayashi, and Y. Kuno. Socially Acceptable Smart Wheelchair Navigation from Head Orientation Observation, International Journal on Smart Sensing and Intelligent Systems vol 7,2, June 2014

# Ultrasonic/Acoustic

**Time-of-flight:** transmitters are mounted on the head and receivers in the environment and the distance is calculated based on the time taken to travel between the two.

**Phase Coherence:** transmitters are placed on the participant and in known environment locations. The phase difference between the signals is used to update the head position.


+: cheap and portable

- : speed of sound

Logitech Trackers, VR Depot, 1996.

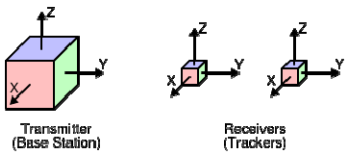
About Our Technology, Virtual Phones Technology, Sony, 2015.

J.D. Mulder, J. Jansen, and A. van Rhijn, An affordable Optical Head Tracking System for Desktop VR/AR Systems, EGVE '03 Proceedings of the workshop on Virtual environments 2003 p.215-223, ACM DL.

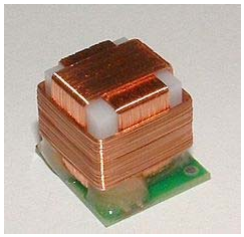
# Electromagnetic

Three mutually orthogonal coils can accurately measure location and orientation:

- Current is induced in presence of an electromagnetic field
- Amplitude and phase tells location and orientation




An issue with this kind of tracking is that many common objects, particularly ones with significant amounts of metal contained therein, can disrupt the magnetic fields.



# Inertial

- Inertial head tracking utilizes accelerometers and gyroscopes to measure head tilting and movement.
- This has become a very popular choice for head tracking as cell phones have encouraged the development of small, relatively inexpensive, and accurate sensors.
- There is an issue of error drift with inertial head tracking, so most use hybrid with inertial.

E. Fuchs, Inertial Head-Tracking, M.S. Thesis, EE and CS, MIT, Sept 1993.

# Hybrid

- One of the most common ways to get around the flaws of any method of head tracking is to combine it with another method.
- All of the hybrid techniques seem to result in accurate head tracking, but the optical-inertial combination does result in higher latency.

S. Yoshida, Introducing: Project Morpheus, Playstation.blog, 19 Mar 2014.
E. Foxlin, M. Harrington, and Y. Altshuler, Miniature 6-DOF inertial system for tracking HMDs, SPIE vol. 3362, Helmet and Head-Mounted Displays III, AeroSense 98, April 13-14, 1998.
A. Hogue, M.R. Jenkin, and R.S. Allison, An Optical-Inertial Tracking System for Fully-enclosed VR Displays, York University, Toronto, Ontario, Canada.
Building a Sensor for Low-Latency VR, Oculus VR, 4 Jan. 2013.

# Who does what?

- No one seems to be using a mechanical arm for head tracking anymore.
- Optical head tracking is available from FreeTrack for use with a regular web cam. There have also been head tracking solutions using multiple Wiimotes for their optical sensors.
- Acoustic or Ultrasonic head tracking seem to be of interest mostlly to Logitech and Sony, and that work is less current than other options.
- Electromagnetic head tracking is used by Polhemus “for both real and simulated aircraft cockpits and ground vehicles.”
- Inertial head tracking is so affordable that it is done largely by DIYers using either cell phones or Arduino components.
- A hybrid of inertial and infrared tracking is being used currently by Oculus VR.
- A hybrid of optical and inertial tracking is being used in Playstation’s Project Morpheus.

•Welcome to the FreeTrack Website, FreeTrack, 2011.
•Head Trackers, Polyhemus, 2015.

# Observations

- Head tracking hasn't changed much since the 90's
- Head tracking technologies have, however, become smaller, more wearable, and better overall at what they do.

Photo 1. HMD with four optical sensors aimed upward

R. Azuma, Tracking requirements for augmented reality. *Commun. ACM* 36, 7 July 1993, 50-51.

# What is Body Tracking

Tracking:

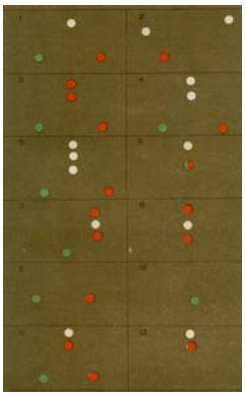
- A Group of People
- A Single Person
- Individual Parts of a Person

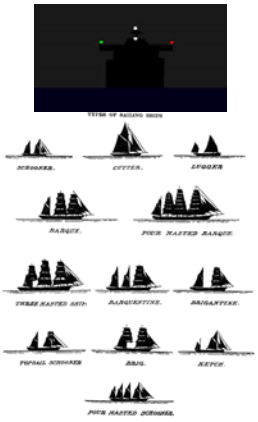
# Historical Tracking

- Skeletal Tracking

# Historical Tracking

- Shape Tracking
  - From contours
- Structured Light



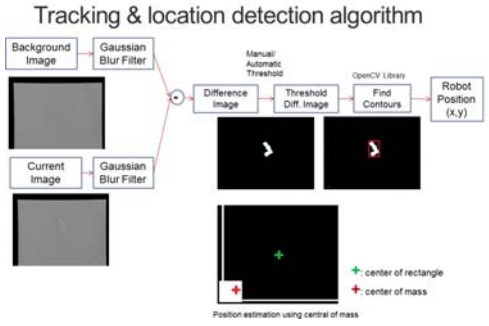


# Person Tracking

- Background subtraction
  - Optical Flow
- People Detector (Classifier)
  - Kalman filter or Optical Flow

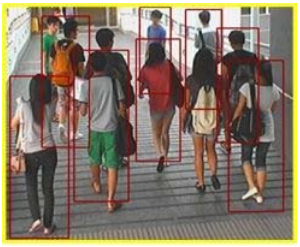
# Background Subtraction

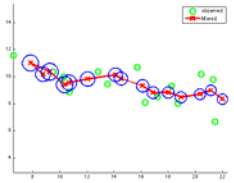
- Get Background
- Get difference between background and new frame
- Get contour of revealed object
- Track the position of that object



# Classification

- Cascading Classifiers built from examples
  - OpenCV does this for you
  - This also allows the camera to be moving
- Track detected people
  - Kalman Filter
    - Smoothing / Predictive Approach



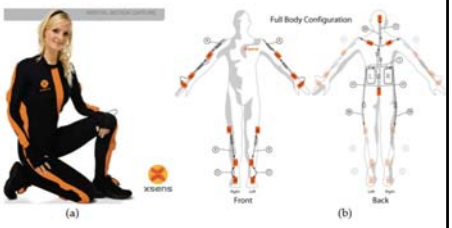


# Green Screen

Using color substitution to replace color with background image

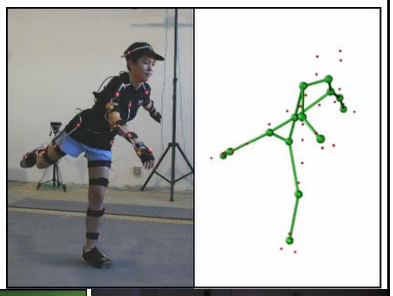
# Full Body Skeleton

- Known as Mechanical Motion Capture
  - Exo-skeleton
  - Extremely precise
  - Costs - $25,000 to $75,000
  - Even provide limited force-feedback
- Inertial Motion Capture – Inertial sensors are placed on the body, using gyroscopes to capture motion of joints relative to each other.
  - No cameras, no markers, no emitters.
  - Provides relative movements




# Motion Capture

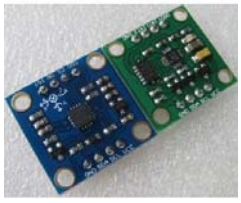
- Using retro-reflective markers placed on body with lights and cameras placed around the room
- Self emitting markers that require no lights placed (still need cameras)
- Use multiple cameras so they can triangulate where marker is in space
- Magnetic Systems: Uses magnetic flux of three orthogonal coils on both transmitters and receivers to calculate position.



# Video Game Influence – Motion Controls

- The Wii is the "first" to do motion-based control for videogames
- Uses IR, Accelerometer, and gyroscope

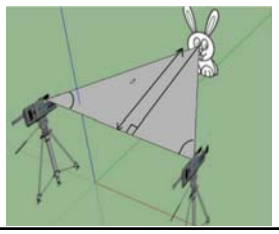
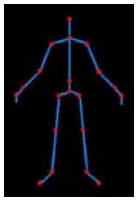


# Kinect – Tracking for the Masses

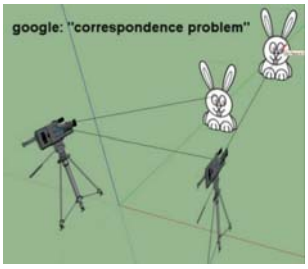
- Not the first 3D camera, but certainly the most influential.
- So what, calculating depth is easy from two cameras

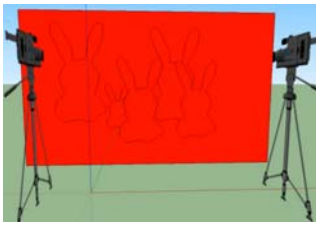


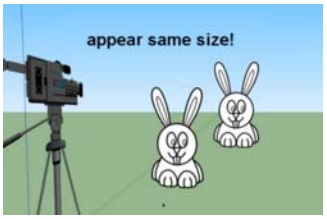



# Kinect

- But what happens when you have 2 bunnies that appear the same size or same color?
- The Kinect handles all these!

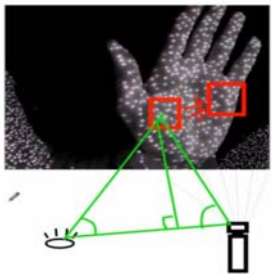


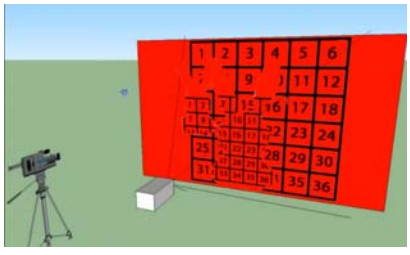






# Kinect

- Kinect paints scene with unique dot patterns which allows differentiation no matter what the colors are.
- No group of dots is like any other. So now the Kinect knows the angle of every group
- Known as Semi-passive imperceptible marker

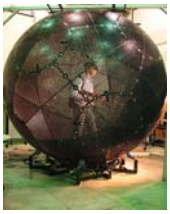




# Omni Directional Treadmill

- Allows the user to walk in any direction and have their local position tracked.
  - Some are passive (meaning the user is moving the track)
  - Some are active, tracking the user and moving the track as needed.

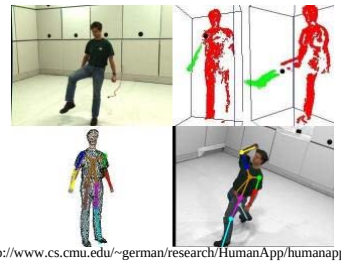
https://www.youtube.com/watch?v=BQw1tsgrJOs



http://www.virtuix.com/

# Markerless Motion Capture

- All the tracking is done passively.
- Silhouette modeling and approximating a skeleton.
- Temporal Shape from Silhouettes



http://www.cs.cmu.edu/~german/research/HumanApp/humanapp.html


tp://www.inition.co.uk/product/organic-motion-stage

# Exo-Suit

- Augmenting human ability
  - Strength, agility, dexterity
- Must use predictive models to guess what the user is going to do.
  - Combination of Mechanical Motion Capture and advanced models.

# EEG for Motion Input

Using EEG (reading your brain) to provide motion input

- Primarily used in VR and those with disabilities

http://inc.ucsd.edu/~poizner/motioncapture.html

https://emotiv.com/epoc.php/