PA201
Virtual Environments

Lecture 2

Virtual Reality Tracking

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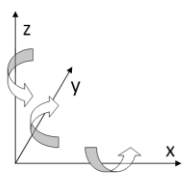
Motivation

- Different ways of interaction in VR
  - More natural
  - Higher level of immersion
  - Task performance
  - Control navigation
  - Control interaction
    - How do we track the objects/users?
    - How do we determine what the user sees?

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Requirements

- Signaling
  - Button presses
  - Other user input
- Pose calculation
  - Position (x, y, z)
  - Orientation (yaw, pitch, roll)



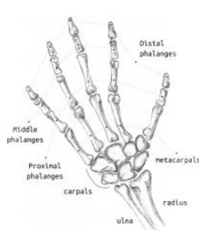
http://www.tmt.unze.ba/zbornik/TMT2010/091-TMT10-029.pdf

DOF

- Degrees of freedom (DOF) are the set of independent displacements and/or rotations that specify completely the position and orientation of the body or system
- 1 DOF system
  - Volume control, speed control, sliding along a straight line etc
- 2 DOF system
  - Mouse, joystick, drawing tablet etc
- 3 DOF system
  - Position or orientation
- 6 DOF system
  - Position and orientation

More DOFs

- More DOFs (more moving parts)
  - Human hand has 22 possible movements, so tracking it completely would be 22 DOF
    - Position, orientation, joints
  - Humans total over 100 DOF



Top view of simplified human hand kinematic model (22 DOFs)

http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

What to Track

- Head pose
- Hand pose
- Other body part(s)
- Other objects
- Trackers can do:
  - Only position
  - Only orientation
  - Both position and orientation

What to Track .

- If tracking of other body parts beside the head is required, their respective positions and orientations would be measured using special purpose tracking probes attached to the parts
- The body parts' locations could then be represented with respect to the head coordinate system

https://pdfs.semanticscholar.org/ce53/48128f94f3383bdc4eb15fb4eaf3721d521f.pdf

Applications of Tracking

- Used in VR systems
  - Used in CAVEs
  - Not needed for VR training environments (e.g. flight simulators)
- Essential for AR systems
- Beneficial for geo-location
  - Positioning (e.g. "you are here")
  - Tracking (e.g. "where is my iPhone?")
  - Navigation (e.g. how to get from A to B)
  - Geo-fencing (e.g. turn off alarms in cinema)

http://www.cs.tut.fi/courses/SGN-5406/lectures/VR7-sensors.pdf

Tracking Properties

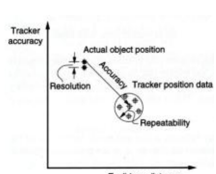
Evaluation Criteria

- Data returned
- Spatial distortion (accuracy)
- Resolution
- Jitter (precision)
- Drift
- Lag
- Update Rate
- Range
- Interference and noise
- Mass, Inertia and Encumbrance
- Number of Tracked Points Durability
- Wireless
- Price

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Tracker Accuracy

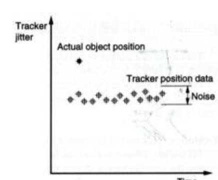
- Difference between an object's pose and the reported pose
  - Separate for position and rotation
  - Not the same thing as resolution
    - Resolution is the minimum change that the sensor can detect
- Typically degraded with distance from the origin of the reference system of coordinates
  - Operating range



http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

Tracker Jitter

- The change in tracker output when the tracked object is stationary
- A tracker with no jitter gives constant value as output if the object is stationary
- Should be minimized
- Unwanted effects in graphics
  - Tremor
  - Jumpy virtual objects
  - Can be filtered -> latency



http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

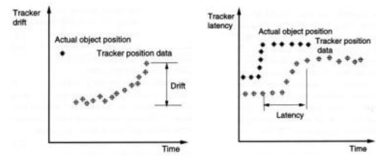
Latency

- What makes up latency (or Lag)?
  - Acquisition
  - Transmission
  - Filtering
- Latency = t_1 - t_0
  - where:
    - t_0 time when sensor is at point p
    - t_1 time when sensor reports p

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Tracker Drift and Latency

- Drift: the steady increase in tracker error with time
  - As time passes, the tracker inaccuracy grows



http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

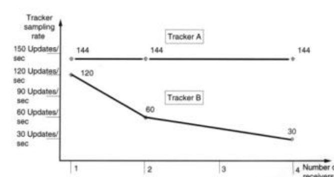
Update Rate

- Number of tracker position/orientation samples per second
  - High update rate != accuracy
  - Poor use of update information may result in more inaccuracy
  - Communication pathways and data packet size are important
  - Typically 30-240 datasets/s

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Multiplexing Effect

- If a tracker measures several objects, sampling rate can suffer
  - Multiplexing effect



Tracker update rate versus number of tracked objects

http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

Range

- Position and orientation range could be different
- Sensitivity not uniform across all axis
- Working volume
  - What is the shape?
  - Accuracy decreases with distance
  - Range is inversely related to accuracy

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Interference and Noise

- Interference - external phenomenon that degrades system's performance
- Each type of tracker has different causes of interference/noise
  - Occlusion
  - Metal
  - Noise
  - Environmental (e.g. door slamming, air conditioner)

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Principles

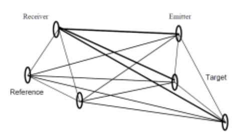
Tracking Principles

- The six main principles of tracking operation include:
  - Time of flight (TOF)
  - Spatial scan
  - Inertial sensing
  - Mechanical linkages
  - Phase difference sensing
  - Direct-field sensing

Rolland, J.P., Baillot, Y., Goon, A.A. A survey of tracking technology for virtual environments, Fundamentals of wearable computers and augmented reality, 2001. (https://pdfs.semanticscholar.org/ce53/48128f94f3383bdc4eb15fb4eaf3721d521f.pdf)

Time of flight (TOF)

- TOF systems rely on the measure of distance between features attached on one side to a reference and on the other side to a moving target
- These distances are determined by measuring the time of propagation of pulsed signals between pairs of points
  - Under the assumption that the speed of propagation of the signals is constant



Principle of a TOF tracking system

Rolland, J.P., Baillot, Y., Goon, A.A. A survey of tracking technology for virtual environments, Fundamentals of wearable computers and augmented reality, 2001. (https://pdfs.semanticscholar.org/ce53/48128f94f3383bdc4eb15fb4eaf3721d521f.pdf)

Spatial Scan

- Spatial scan trackers compute the position and the orientation of a target
  - The optical sensors are typically cameras
- The principle is based on either:
  - The analysis of 2D projections of image features
  - On the determination of sweep-beam angles

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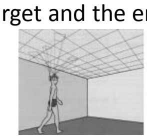
Spatial Scan Configurations

- Outside-in systems employ video cameras that are placed on the reference and record features of the target
  - This technique is widely employed
- In an inside-out configuration the sensor is on the target and the emitters are on the reference



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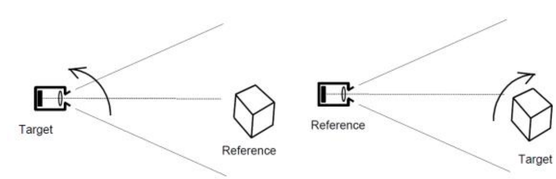
Outside-In v.s. Inside-Out Tracking



Inside-out configuration: *The rotation of the camera, held by the target in this case, produces a large motion of the image of the cube on the CCD camera.*

Outside-in configuration: *The rotation of the cube, the target in this case, produces a small motion of the image on the CCD camera.*

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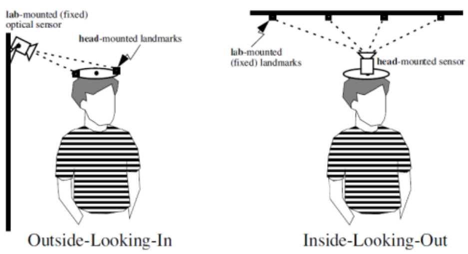
Outside-In v.s. Inside-Out Tracking .



Billinghurst, M. COSC 426: Augmented Reality, July 26th 2013.

Inertial Sensing

- The principle of inertial sensing is based on the attempt to conserve either
  - A given axis of rotation
    - Mechanical gyroscopes
  - A position
    - Accelerometers

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Intersense

- InertiaCube 3
  - Orientation, inertial sensors
  - 2000 €, wireless 3000 €

- InterTrax2
  - Discontinued

- IS-900
  - 6 DOF, inertial sensors + ultrasound
  - Very accurate and fast
  - 9 - 43,000 €
- IS-1200
  - For mobile augmented reality
  - InertiaCam looks for fiducials
  - Supports over 30,000 fiducials

http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

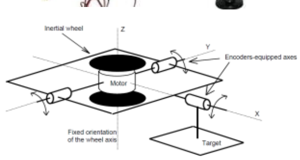
InertiaCube4

- Sourceless 3DOF tracking with full 360° range
- Accuracy of 1° yaw, 0.25° pitch & roll
- 200 Hz update rate
- 2000° maximum angular rate
- Adjustable output filters and rotational sensitivity
- Prize: $995

http://www.intersense.com/pages/18/234

Mechanical Gyroscope

- Mechanical gyroscopes are based on the principle of conservation of angular momentum
  - The wheel is mounted on a frame so that the external moments are minimized
  - This allows the target to turn around the wheel without experiencing a change in the direction of its axis

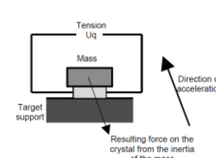


Structure of a mechanical gyroscope

Rolland, J.P., Baillot, Y., Goon, A.A. A survey of tracking technology for virtual environments, Fundamentals of wearable computers and augmented reality, 2001. (https://pdfs.semanticscholar.org/ce53/48128f94f3383bdc4eb15fb4eaf3721d521f.pdf)

Accelerometer

- An accelerometer measures the linear acceleration of an object to which it is attached
- A single-degree-of-freedom device which has
  - Some kind of mass
  - A spring like supporting system
  - A frame structure with damping properties
- It may rely for example on a mass mounted on a piezo-electric crystal and attached to the target



Structure of an accelerometer

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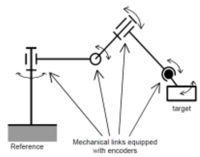
Mechanical Linkages

- Two types have been used
- One is an assembly of mechanical parts that can each rotate providing the user with multiple rotation capabilities
  - The orientation of the linkages is computed from the various linkages angles measured with incremental encoders or potentiometers
  - This type of tracking system uses mechanical linkages between the reference and the target



Structure of a typical mechanically linked tracking system

Rolland, J.P., Baillot, Y., Goon, A.A. A survey of tracking technology for virtual environments, Fundamentals of wearable computers and augmented reality, 2001. (https://pdfs.semanticscholar.org/ce53/48128f94f3383bdc4eb15fb4eaf3721d521f.pdf)

Mechanical Linkages .

- Other types of mechanical linkages are wires that are rolled on coils
  - A spring system ensures that the wires are tensed in order to measure the distance accurately
- The degrees of freedom sensed by mechanical linkage trackers are dependent upon the constitution of the tracker mechanical structure

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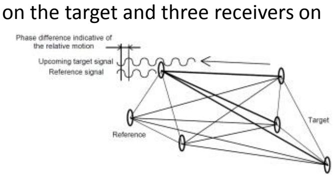
Phase Difference

- Measures the relative phase of an incoming signal from a target and a comparison signal of the same frequency located on the reference
  - As in the TOF approach, the system is equipped with three emitters on the target and three receivers on the reference



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Direct-Field

- Two different types:
  - Magnetic field
    - i.e. Magnetometers
  - Gravitational field
    - i.e. inclinometer

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Magnetometers

- Magnetometers measure the orientation of an object with respect to the magnetic field of the earth
  - Magnetic field sensors include fluxgate, Hall effect, magneto-resistive, and magneto-inductive sensors
  - The most relevant magnetometers use magneto-inductive sensors

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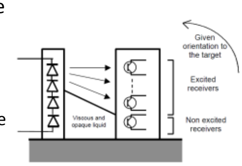
Inclinometers

- An inclinometer operates on the principle of a pendulum
- Common implementations use electrolytic or capacitive sensing of fluids
  - A simple implementation may measure the relative level of fluids in two branches of a tube to compute inclination
  - More advanced implementations include an optical inclinometer



Principle of operation and structure of an optical inclinometer

Rolland, J.P., Baillot, Y., Goon, A.A. A survey of tracking technology for virtual environments, Fundamentals of wearable computers and augmented reality, 2001. (https://pdfs.semanticscholar.org/ce53/48128f94f3383bdc4eb15fb4eaf3721d521f.pdf)

Hybrid Approaches

- Hybrid technology refers to the combination of various technologies and systems based on different principles of operation
  - i.e. TOF measurements versus phase difference measurements
- Pros:
  - Both relative and absolute measurements
  - Make exhaustive measurements
- Cons:
  - Complex
  - Cost

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Video Tracking

Vision based tracking

- Video is processed (computer vision)
  - Very heavy calculation
  - Markers, chroma-key helps a lot
  - OpenCV, http://opencv.willowgarage.com/
- Image filtering, contour finding
- Feature extraction, object recognition
- Recognition of forms

http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

Feature-based Object Detection

- In feature-based object detection, standardization of image features and registration (alignment) of reference points are important
- Shape-based approaches
  - Hard due to:
    - The difficulty of segmenting objects of interest in the images
    - Many objects with occlusions and shading
  - Images may need to be filtered depending on the application
    - Different object types such as persons, flowers, and airplanes may require different algorithms
    - For more complex scenes, noise removal and transformations invariant to scale and rotation may be needed

http://medianet.kent.edu/surveys/IAD01F-objdetection/index.html

Feature-based Object Detection .

- Color-based approaches
  - Not always useful but easy to be acquired
  - Low cost

http://medianet.kent.edu/surveys/IAD01F-objdetection/index.html

Template-based object detection

- Object detection matches features between the template and the image sequence under analysis
  - If a template describing a specific object is available
  - Object detection with an exact match is computationally expensive
  - Quality of matching depends on the **details** and the **degree of precision** provided by the object template
- Two types exist:
  - Fixed template matching
  - Deformable template matching

http://medianet.kent.edu/surveys/IAD01F-objdetection/index.html

Fixed template matching

- Useful when object shapes do not change with respect to the viewing angle of the camera
- Two major techniques
  - Image subtraction
    - The template position is determined from minimizing the distance function between the template and various positions in the image
  - Correlation
    - Matching by correlation utilizes the position of the normalized cross-correlation peak between a template and an image to locate the best match

http://medianet.kent.edu/surveys/IAD01F-objdetection/index.html

Deformable Template Matching

- Deformable template matching approaches are more suitable for cases where objects vary due to rigid and non-rigid deformations
  - These variations can be caused by either the deformation of the object per se or just by different object pose relative to the camera
  - Because of the deformable nature of objects in most video, deformable models are more appealing in tracking tasks

http://medianet.kent.edu/surveys/IAD01F-objdetection/index.html

Motion Detection

- Motion detection complicates the object detection problem by adding object's temporal change requirements,
  - However it also provides another information source for detection and tracking
- A large variety of motion detection algorithms have been proposed

http://medianet.kent.edu/surveys/IAD01F-objdetection/index.html

Object Tracking using Motion

- Motion detection provides useful information for object tracking
  - Tracking requires extra segmentation of the corresponding motion parameters
- Two categories:
  - Motion-based
    - Rely on robust methods for grouping visual motion consistencies over time
    - Fast but have considerable difficulties in dealing with non-rigid movements and objects
  - Model-based
    - Explore the usage of high-level semantics and knowledge of the objects
    - More reliable compared to the motion-based
    - Suffer from high computational costs for complex models
      - Due to the need for coping with scaling, translation, rotation, and deformation of the objects

http://medianet.kent.edu/surveys/IAD01F-objdetection/index.html

Face Recognition

- Easy way is to compare a selection of facial features from the image and a face database
- Typically used in security systems and can be compared to other biometrics such as fingerprint or eye iris recognition systems
  - Recently, popular as a commercial identification and marketing tool
- Face Recognition
  - http://www.face-rec.org/

Camera Tracking

- A single camera can do 2D tracking
  - Typically used in second person VR
    - Participants watch themselves in the virtual world
    - The video source is used both for tracking the user and adding the user's image into the virtual world
- Usually multiple cameras needed for 3D tracking
  - Several dots are needed to acquire the orientation
  - The positions of the light dots in the image give the directions of the objects as seen from the camera
  - The operation range can be very large
  - Requires calculation, can be expensive and slow
  - Time-of-flight cameras send IR

http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

Videometric Tracking

- Inside-looking-out
- Video camera on the tracked object
- The camera watches surroundings
- VR system analyzes images
  - Try to locate landmarks
  - Derive camera's relative position to the landmarks
- Often used in augmented reality systems
  - Can operate in a large area, also outdoors
    - i.e. a camera on the HMD enables to determine the corners of the room
- Computational resources needed to do the image analysis becomes a consideration
- A single camera can determine its own 6-DOF position
  - Multiple reference points needed

http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

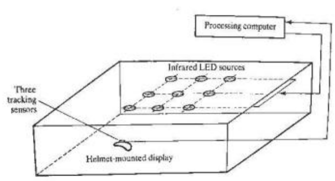
Videometric Tracking .

- The location of the landmarks must me known or be discernible from other data
  - Otherwise calculations get very complex and probability for errors grow
  - Landmark color and shape different from surroundings
    - Reference points
  - Using LED lights at certain spots
  - Using special easily distinguishable patterns

http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

Videometric Tracking ..

- Usage of LED lights
- Infrared sensitive cameras
- Activating the lights as patterns



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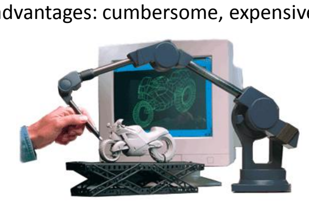
Tracker Types

Mechanical Trackers

- Mechanical tracking devices are widely used nowadays
- The lack of certain hardware devices (i.e. transmitter/receiver) makes mechanical trackers much less sensitive to their immediate environment than other types of trackers
  - i.e. Electromagnetic trackers
- Two different types of mechanical devices are currently used in the industry/research including
  - The arm
  - Force sensing ball

Mechanical Trackers .

- Idea: mechanical arms with joint sensors
  - Advantages: high accuracy, haptic feedback
  - Disadvantages: cumbersome, expensive



Billinghurst, M. COSC 426: Augmented Reality, July 26th 2013.

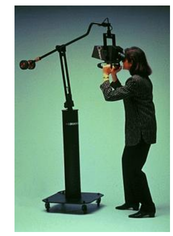
Mechanical Trackers ..

- The ‘arm’ or ‘boom’ sensing device takes measurements in rotation using either a potentiometer or optical encoders
- The device measures the forces exerted and it is therefore applied in force-sensing joysticks

BOOM 3C

Mechanical Trackers - BOOM

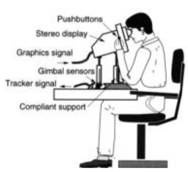
- A BOOM display is an HMD (head mounted display) mounted on the end of a mechanical arm
  - The system detects the position and orientation by this arm
  - Advantage is very high update rate
  - Disadvantage is limited range of user´s motion



BOOM HF

Mechanical Trackers - BOOM Tabletop

- A tabletop model



http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

Mechanical Trackers - Motion Capture Suit

http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

Electromagnetic Trackers (EM)

- Electromagnetic trackers are comprised of two simple electronic systems:
  - A transmitter
  - A receiver
- Usually, their main function is to detect the generated variations of the received signal
- In other words, the position and orientation of the transmitters can be calculated

Polhemus FASTRACK electromagnetic tracker

EM Characteristics

- Data returned: 6 DOF
- Spatial distortion – 0.6 mm, 0.025°
- Resolution – 0.00508 mm, 0.025° / inch from receiver
- Jitter (precision) – mm to cm
- Drift - none
- Lag – reported 4 ms
- Update Rate - 120 Hz
- Range - 5 ft
- Number of Tracked Points – 16 (divides update rate)
- Wireless - yes
- Interference and noise – metal, earth
- Mass, Inertia and Encumbrance - minimal
- Durability - high
- Price - $4000+

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

EM Advantages

- Measure position and orientation in 3D space
- Does not require direct line of sight
- Low encumbrance
- Cost
- Good performance close to emitter
- Lag
- Can be built ‘into’ devices
- Earth magnetic field good for 3DOF

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

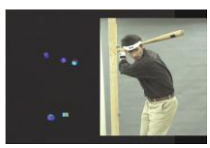
EM Disadvantages

- Accuracy affected by
  - DC: Ferrous metal and electromagnetic fields.
  - AC: Metal and electromagnetic fields
- Operate on only one side of the source
  - i.e. the working hemisphere
- Low range (effectively 5’ – does not scale well)
- Calibration

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

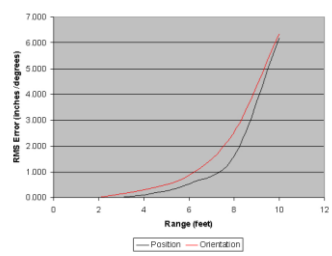
EM Applications

- Ascension Flock of Birds
- Polhemus Fastrak
- Extremely popular
- Good for many applications
  - CAVEs (remove metal)
  - HMDs
  - Projection displays
  - Fishtank



http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Tracking Error



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Optical Trackers

- Optical trackers have the ability to operate over large areas in indoor or outdoor environments
- However, the implementations of optical tracking systems are diverse using
  - Infra-red LEDs, photodiodes, lasers, video cameras, web-cameras
  - Combinations of these

Optical Trackers .

- The creation and maintenance of a corresponding virtual line of sight is essential for the operation of any optical tracking system
- They function by placing the light sources or fiducials on the object to be tracked and then determine the position of the object using light detectors

Cheap Optical Trackers

Optical Tracker

- Idea
  - Image Processing and Computer Vision
- Specialized
  - Infrared, Retro-Reflective, Stereoscopic
- Monocular Based Vision Tracking

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Optical Tracking Technologies

- Scalable active trackers
  - InterSense IS-900, 3rd Tech HiBall
- Passive optical computer vision
  - Line of sight, may require landmarks
  - Can be brittle
- Computer vision is computationally-intensive

3rd Tech, Inc.

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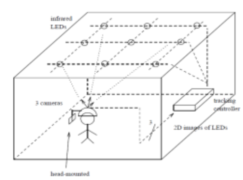
HiBall Tracking System (3rd Tech)

- Inside-Out Tracker
  - $50K USD
- Scalable over large area
  - Fast update (2000Hz)
  - Latency Less than 1 ms
- Accurate
  - Position 0.4mm RMS
  - Orientation 0.02° RMS



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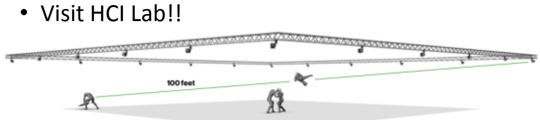
Motion Tracking

- Very popular for VR
- Need markers
- Can track whole body
- Expensive solution
- A feasible tool for creating animation
- Visit HCI Lab!!



Motion Tracking .

- Can be based on any tracking method
  - Often cameras are used
  - Reflectors or LEDs used
  - Facial 1-2 cameras
  - Full body 4-6 cameras
- Often not real time (Movies)
- The movements are recorded and animation then rendered

WorldViz PPT

- Freedom of movement in VR
  - Track multiple users over large areas while maintaining precision and accuracy
  - Quickly configure and calibrate with user-friendly, stream-lined user interface
  - Real-time sub-millimeter accuracy
  - Integrate with various other real-time rendering software

https://www.worldviz.com/virtual-reality-motion-tracking/

OptiTrack

- High-speed, low latency
- Head, controller & body tracking
- Track any object type using a single infrared LED marker configuration
  - Allows for identically manufactured HMDs, weapons, controllers, etc to be tracked simultaneously

http://optitrack.com/motion-capture-virtual-reality/

VRECKO

- Modular framework for experiments in VR

Polygonal mesh editing

Motion Capture

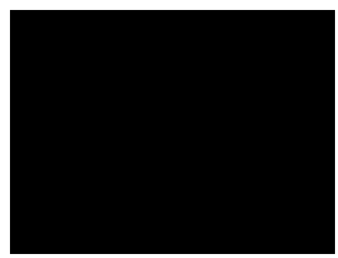
Physical simulations

Geometrical sculpture

http://vrecko.cz/

75

VRECKO Video



http://vrecko.cz/research/vekva/freehand-painting/

76

Valve's Lighthouse Tracking

- The main idea behind tracking is flooding a room with non-visible light, Lighthouse functions as a reference point for any positional tracking device (like a VR headset or a game controller) to figure out where it is in real 3D space

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

Valve's Lighthouse Tracking .

- Valve's Lighthouse boxes <u>don't have any cameras</u>
- They just fire light out (sixty times every second) into the world to help ships (or VR headsets) navigate on their own
- That light comes from a whole bunch of stationary LEDs, plus a pair of active laser emitters that spin like crazy

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

Valve's Lighthouse Tracking ..

- The receiver (VR headset or controller) is covered with little photosensors that detect the flashes and the laser beams
- When a flash occurs, the headset simply starts counting (like a stopwatch) until it "sees" which one of its photosensors gets hit by a laser beam
- It uses the relationship between where that photosensor exists on the headset, and when the beam hit the photosensor, to mathematically calculate its exact position relative to the base stations in the room

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

Video UW VR

Acoustic Trackers

- Acoustic tracking systems make use of ultrasonic signals to avoid interference with the detectable spectrum of human users
  - Based on TOF measurement
    - Measures the time needed for the sound to reach the receivers and then the distance is calculated based on the speed of sound in the air, producing absolute position and orientation values

Acoustic Trackers .

- Since TOF can only measure distance, to achieve 3D tracking a combination of transmitter and receiver is required
  - For 3 DOF one transmitter and one receiver is required
- For 6 DOF tracking 3 transmitters and 3 receivers are necessary

Acoustic Magic

Acoustic Trackers Pros and Cons

- Pros: Small, Cheap
- Cons: 3DOF, Line of Sight, Low resolution, Affected Environment Condition (pressure, temperature)

Ultrasonic Logitech

IS600

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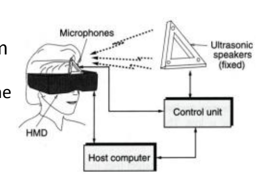
Ultrasound Head Tracker

- Transmitter, receiver and electronics unit
- Transmitter is a set of three ultrasonic speakers 30cm from each other
  - Rigid and fixed triangular frame
- Receiver is a set of three microphones
  - Placed at the top of the HMD
  - May be part of 3D mice, stereo glasses, or other interface devices
- Range typically about 1.5 m

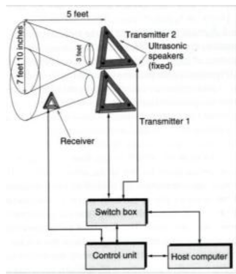


Ultrasound head tracker architecture

http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

Ultrasound Extended Range

- Certain applications require larger user motion volume than a transmitter can cover
- Several transmitters multiplexed with one receiver
- Only one transmitter works at a time
- The computer switches the transmitters



http://www.fkm.utm.my/~kasim/eng_design/vr/VR.Tracking.pdf

Other Trackers

Gloves

- Allow natural interaction with virtual world
  - Grab
  - Gestures
- Two types
  - Force feedback
  - Pinch gloves

Angle Measurement

- Measurement of the bend of various joints in the user's body
- Used for:
  - Reconstruction of the position of various body parts (hand, torso).
  - Measurement of the motion of the human body (medical)
  - Gestural Interfaces
    - Sign language

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Angle Measurement Technology

- Optical Sensors
  - Emitter and receiver on ends of sensor
  - As sensor is bent, the amount of light from emitter to receiver is attenuated
  - Attenuation is determined by bend angle
  - Examples: Flexible hollow tubes, optical fibers
  - VPL Data Glove

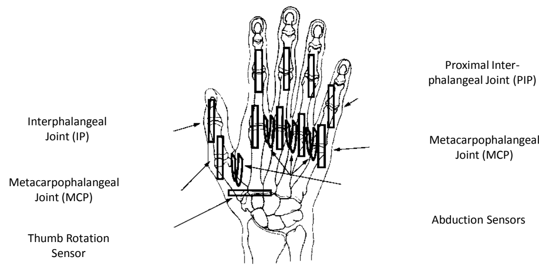
http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Angle Measurement Technology .

- Strain Sensors
  - Measure the mechanical strain as the sensor is bent
  - May be mechanical or electrical in nature.
  - P5 Glove $25 (!)
  - Cyberglove (Virtual Technologies)

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Joints and Cyberglove Sensors



http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Angle Measurement Technology ..

- Exoskeletal Structures
  - Sensors mimic joint structure
  - Potentiometers or optical encoders in joints report bend
  - Exos Dexterous Hand Master

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Exoskeleton & Angle Sensors

- Analogous
- Tethered
- No identification problem
- Real-time
- No range limit
- Rigid body approximation

Pinch Gloves

- Have sensor contacts on the ends of each finger
- Good as interfaces
- Good at grabbing
- No feedback

Monkey

- High accuracy
- High data rate
- Not realistic motion
- No paid actor

http://www.cise.ufl.edu/~lok/teaching/ve-s09/tracking.ppt

Videos

- Dexmo exoskeleton glove lets you feel objects in virtual reality
  - https://www.youtube.com/watch?v=nin1_0EHU5g
- Stelarc: EXOSKELETON
  - https://www.youtube.com/watch?v=vj0JUfmxkv4
- Paralysed walk again thanks to revolutionary robotic exoskeleton that responds to brain waves
  - https://www.youtube.com/watch?v=OL2FUKdaxOI

Outdoor Tracking

GPS Trackers

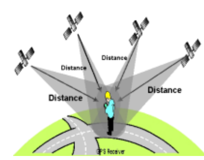
- GPS is a technology widely used for outdoor tracking
- The most important categories include
  - Standard GPS
  - Differential GPS
  - Real-time kinematic GPS

GPS Trackers .

- Standard GPS is a satellite based positioning system that utilizes a total of 29 satellites
  - This will change with Galileo!
- The position of the user is determined by processing radio signals from the satellites
- In theory, GPS systems can estimate the user's position, by calculating the arrival time of at least three satellite signals

GPS Trackers .

- Satellites send position + time
- GPS Receiver positioning
  - 4 satellites need to be visible
  - Differential time of arrival
  - Triangulation
- Accuracy
  - 5-30m+, blocked by weather, buildings etc



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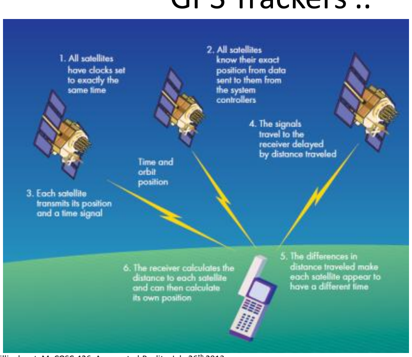
GPS Trackers ..



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Problems with GPS

- Takes time to get satellite fix
  - Satellites moving around
- Earths atmosphere affects signal
  - Assumes consistent speed (the speed of light)
  - Delay depends where you are on Earth
  - Weather effects
- Signal reflection
  - Multi-path reflection off buildings
  - Signal blocking
  - Trees, buildings, mountains
- Satellites send out bad data
  - Misreport their own position

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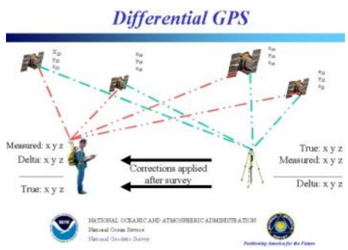
Differential GPS

- Uses emitting ground stations that refine the resolution
- Accurate to < 5cm close to base station
  - 22m/100 km
- Expensive
  - $20-40,000 USD



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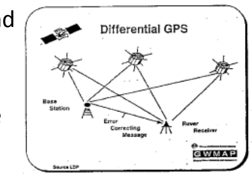
Differential GPS .

- The mobile GPS receiver monitors signals from a fixed radio transmitter and another GPS receiver
- To refine the resolution the transmitter sends the corrected co-ordinates
  - Based on the difference between the known and the computed positions



Assisted-GPS (A-GPS)

- Use external location server to send GPS signal
  - GPS receivers on cell towers, etc
  - Sends precise satellite position (Ephemeris)
- Speeds up GPS Tracking
  - Makes it faster to search for satellites
  - Provides navigation data (don't decode on phone)
- Other benefits
  - Provides support for indoor positioning
  - Can use cheaper GPS hardware
  - Uses less battery power on device

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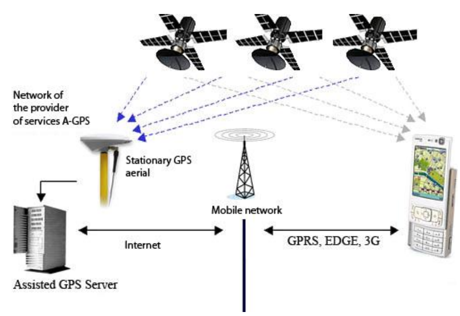
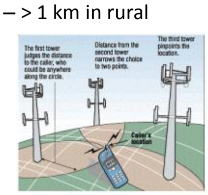
Assisted-GPS (A-GPS)

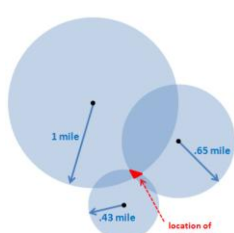


http://gps-response.com/61-a-gps.html

Cell Tower Triangulation

- Calculate phone position from signal strength
  - < 50 m in cities
  - > 1 km in rural





Triangulation - cell phone detected within a certain radius of each of 3 cell towers – the area where each cell tower overlaps the phone is where it is pinpointed.

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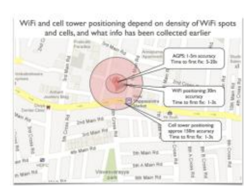
WiFi Positioning

- Estimate location based on WiFi access points
  - Use known locations of WiFi access points
- Triangulate through signal strength
  - i.e. PlaceEngine
- Accuracy
  - 5 to 100m
    - Depending on WiFi density



Eye Tracking

Eye Tracking

- Eye trackers measure rotations of the eye in one of several ways, but principally they fall into three categories:
  - VOG: Measurement of the movement of an object (i.e. special contact lens) attached to the eye
  - Optical tracking without direct contact to the eye
  - EOG: Measurement of electric potentials using electrodes placed around the eyes

https://en.wikipedia.org/wiki/Eye_tracking

Optical Tracking

- Light is reflected from the eye and sensed
  - Video camera or some other specially designed optical sensor
- The information is then analyzed to extract eye rotation from changes in reflections
- To track over time video-based eye trackers typically use
  - The corneal reflection
    - First Purkinje image
  - The center of the pupil as features

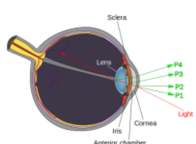


Diagram of light and four Purkinje images

https://en.wikipedia.org/wiki/Eye_tracking

Video Oculography (VOG)

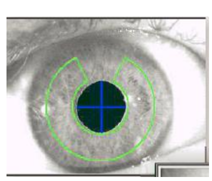
- VOG is a non-invasive, video-based method of measuring horizontal, vertical and torsional position components of the movements of both eyes
  - Using a head-mounted mask that is equipped with small cameras
  - Usually employed for medical purposes


VOG examination in progress

https://en.wikipedia.org/wiki/Video-oculography

VOG Operating Principles

- Iris tracking and high-quality video imaging
- Senses 3D linear acceleration and 3D rotational velocity
- Horizontal, vertical and torsional eye movements

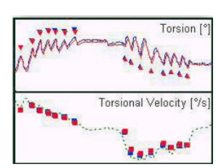


www.smivision.com/en/gaze-and-eye-tracking-systems/products/3d-vog.html

Marchak, F.M., Eye Movement Recording, Veridical Research and Design Corporation, Society for Psychophysiological Research, 14 Sep 2011.

VOG Performance

- Resolution
  - Horizontal : 0.05°
  - Vertical: 0.05°
  - Torsional: 0.1°
- Head motion recording
  - 3D rotational velocity [°/s]
  - 3D linear acceleration [m/s2]



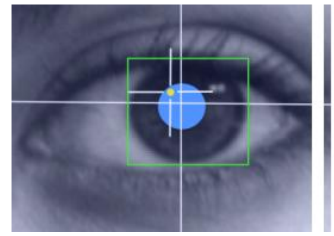
www.smivision.com/en/gaze-and-eye-tracking-systems/products/3d-vog.html

Marchak, F.M., Eye Movement Recording, Veridical Research and Design Corporation, Society for Psychophysiological Research, 14 Sep 2011.

Tradeoffs

- Highly accurate torsional measurement
- Permits comparison of slow phase velocity (SPV) and head rotation velocity
- Useful for research and diagnosis
- Not practical for standard point-of-regard research

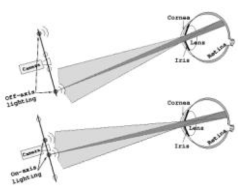
Pupil - Corneal Reflection



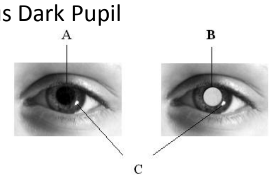
drivingtraffic.com/wp-content/uploads/2010/08/eye.png

Pupil-Corneal Reflection Operating Principles

Bright versus Dark Pupil



http://www.ime.usp.br/~hitoshi/framerate/node2.html

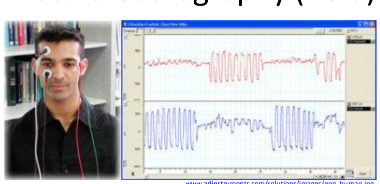


www.archimuse.com/mw2010/papers/milekic/milekic.Fig1.jpg

Pupil - Corneal Reflection Tradeoffs

- Ambient lighting
- Eye color
- Eyelashes
- Makeup

Electro-oculography (EOG)

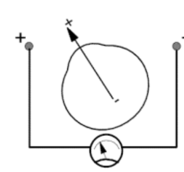


www.adinstruments.com/solutions/images/eog_human.jpg

www.virtualworldlets.net/Shop/ProductsDisplay/VRInterface.php?ID=90

EOG Operating Principles

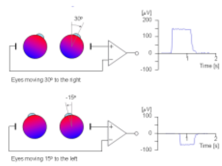
- Permanent potential difference between the cornea and the fundus of 0.4 -1.0 mV
  - Small voltages can be recorded from the region around the eyes which vary as the eye position varies



http://www.liv.ac.uk/~pcknox/teaching/Eymovs/emeth.htm

EOG Performance

- Accuracy : ± 2°
- Maximum rotation: ± 70°
- Linearity decreases progressively for angles > 30°
- Signal magnitude range: 5 – 20 µV/°



http://www.bem.fi/book/28/28.htm

Marchak, F.M., Eye Movement Recording, Veridical Research and Design Corporation, Society for Psychophysiological Research, 14 Sep 2011.

EOG Tradeoffs

- Inexpensive
- Simple operation
- Need for frequent calibration and recalibration
  - Corneoretinal potential can vary diurnally
  - Affected by light and fatigue
  - Drifting- electrode slipping, change in skin resistance
  - Noise from other electrical devices, face muscles
  - Blinking

Marchak, F.M., Eye Movement Recording, Veridical Research and Design Corporation, Society for Psychophysiological Research, 14 Sep 2011.

SMI Eye Tracking HMD for HTC Vive

- SMI's eye tracking HMD based on HTC Vive
  - Tracking : 250 Hz binocular
  - Trackable field of view: Full field of view 110°
  - Accuracy: 0.2°
- Data
  - Inter-pupillary distance (IPD, pupil to pupil distance)
  - Point of regard on display (left and right eye, binocular)
  - Gaze base point
  - Gaze vectors (left and right eye, binocular)

https://www.smivision.com/eye-tracking/product/eye-tracking-htc-vive/

Eye Tracking Videos

- The Eye Tribe Tracker
  - https://www.youtube.com/watch?v=2q9DarPET0o
- GearVR eye tracking demo - using eyes for input
  - https://www.youtube.com/watch?v=VOmBJ7Eim9c
- Tobii Eye Tracker = Higher Gamer Skill Level Increase
  - https://www.youtube.com/watch?v=Kmil1Z84vnI

Questions