CSE 165: 3D User Interaction

Lecture #7: Input Devices

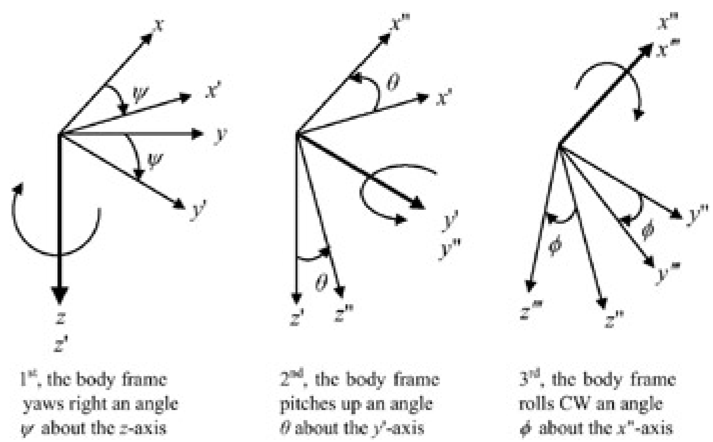
Announcements

- Homework project 2 is on line
  - Due Friday Feb 10th

Quaternions

Rotation Calculations

- Intuitive approach: Euler Angles:
  - Simplest way to calculate rotations
  - Defines rotation by 3 sequential rotations about coordinate axes
  - Example Z-Y-X:



http://www.globalspec.com/reference/49379/203279/3-3-euler-angles

Problems With Euler Angles

- Problems with Euler angles:
  - No standard for order of rotations
  - Gimbal Lock, occurs in certain object orientations
    - Video
      - https://www.youtube.com/watch?v=rrUCBOlJdt4
- Better: rotation about arbitrary axis (no Gimbal lock)
  - Can be done with 4x4 matrix
  - But: smoothly interpolating between two orientations is difficult

➔ Quaternions

Quaternion Definition

- Given angle and axis of rotation:
  - a: rotation angle
  - {nx,ny,nz}: normalized rotation axis
- Calculation of quaternion coefficients w, x, y, z:
  - w = cos(a/2)
  - x = sin(a/2) * nx
  - y = sin(a/2) * ny
  - z = sin(a/2) * nz

Useful Quaternions

w	x	y	z	Description
1	0	0	0	Identity quaternion, no rotation
0	1	0	0	180° turn around X axis
0	0	1	0	180° turn around Y axis
0	0	0	1	180° turn around Z axis
sqrt(0.5)	sqrt(0.5)	0	0	90° rotation around X axis
sqrt(0.5)	0	sqrt(0.5)	0	90° rotation around Y axis
sqrt(0.5)	0	0	sqrt(0.5)	90° rotation around Z axis
sqrt(0.5)	-sqrt(0.5)	0	0	-90° rotation around X axis
sqrt(0.5)	0	-sqrt(0.5)	0	-90° rotation around Y axis
sqrt(0.5)	0	0	-sqrt(0.5)	-90° rotation around Z axis

Quaternions: Further Reading

- Rotating Objects Using Quaternions
  - http://www.gamasutra.com/view/feature/131686/rotating_objects_using_quaternions.php
- Quaternions in Unity 3D:
  - https://docs.unity3d.com/ScriptReference/Quaternion.html
- Quaternions in OpenSceneGraph:
  - http://www.openscenegraph.org/projects/osg/wiki/Support/Maths/QuaternionMaths

Input Devices

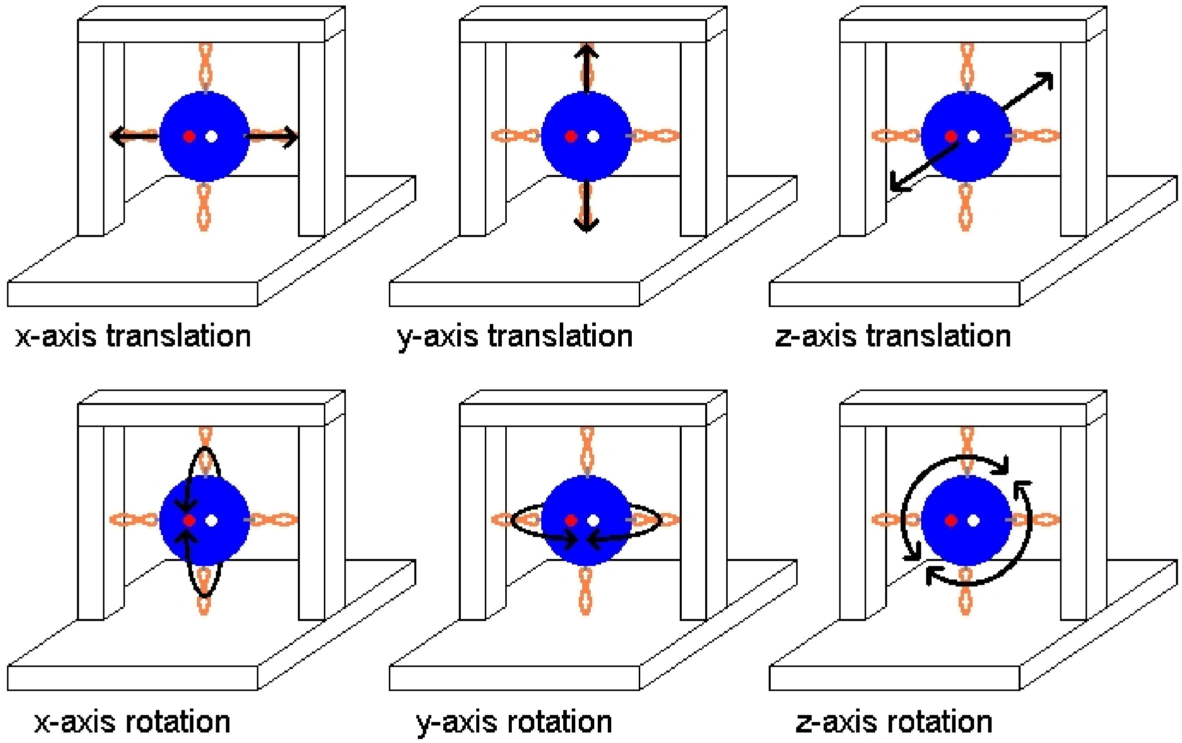
Overview

- Degrees of freedom
- 2-DOF devices
- Relative 6-DOF devices
- Absolute 6-DOF devices
  - mechanical
  - electromagnetic
  - inertial
  - optical
  - ultrasound
  - hybrid
  - special purpose

Degrees of Freedom (DOF)

- DOF: Set of independent displacements that specify completely the displaced or deformed position of a body or system.
- 3 DOF for position:
  - Moving up and down (heaving)
  - Moving left and right (swaying)
  - Moving forward and backward (surging)
- 3 DOF for orientation:
  - Tilting up and down (pitching)
  - Turning left and right (yawing)
  - Tilting side to side (rolling)
  - See also: Euler angles

6 Degrees of Freedom



Keyboard (binary n-DOF) and Mouse (2-DOF)

- Some VR applications are designed for keyboard, mouse or game pads
- Can work well for walk/fly-through applications
- Doesn't work well for 3D selection and manipulation

3 DOF: GPS

- GPS = Global Positioning Satellite system
- GPS receivers determine exactly how long it takes for the signals to travel from each satellite
- Result:
  - Latitude
  - Longitude
  - Altitude

Touch or Pen-based Tablets

- Absolute 2D position
  - 2 DOF
- Microsoft Surface Dial
  - Adds 1 DOF

6-DOF Relative Devices

- Relative position and orientation
- 3dconnexion/Logitech

Spaceball

Space Navigator

Mechanical 6-DOF Tracking

- Fakespace Boom: doubles as a stereo display
- Geomagic Touch: doubles as a haptic feedback device

Fakespace Boom

Geomagic Touch

Electro-magnetic Tracking

- 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

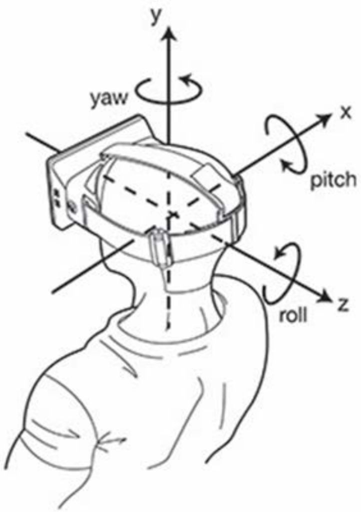
Razer Hydra

Sixense STEM

Inertial Tracking

- Trackers use miniature gyroscopes to measure orientation changes: 3-DOF
- Accelerometers can help calibrate, add position tracking
- Disadvantage: drift between actual and reported values, accumulates over time

Gyro in Oculus Rift DK1



3 Rotational DOF

Optical Tracking: Mocap Devices

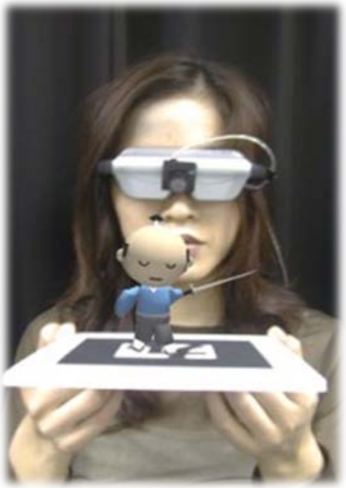
- Infrared (IR) cameras illuminate scene for easier detection of markers
- Multiple markers (highly reflective spheres) arranged in fixed, known configurations allow for 6 DOF tracking

ART Tracking System

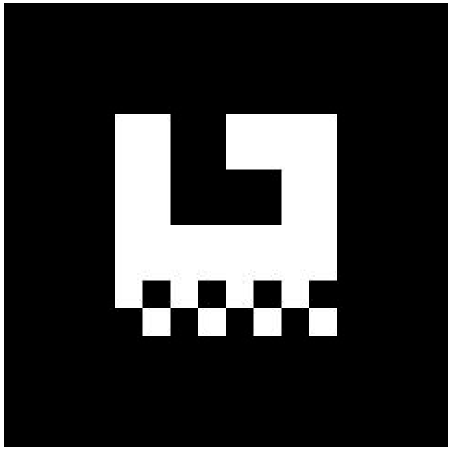
Vicon Tracking System

Optical Tracking: ARToolKit

- Developed in 1999 by Hirokazo Kato, HITLab, University of Washington
- Printable markers
- Camera based (webcam sufficient)
- Flexible marker design
- Simple programming interface
- 6 DOF tracking possible



ARToolKit



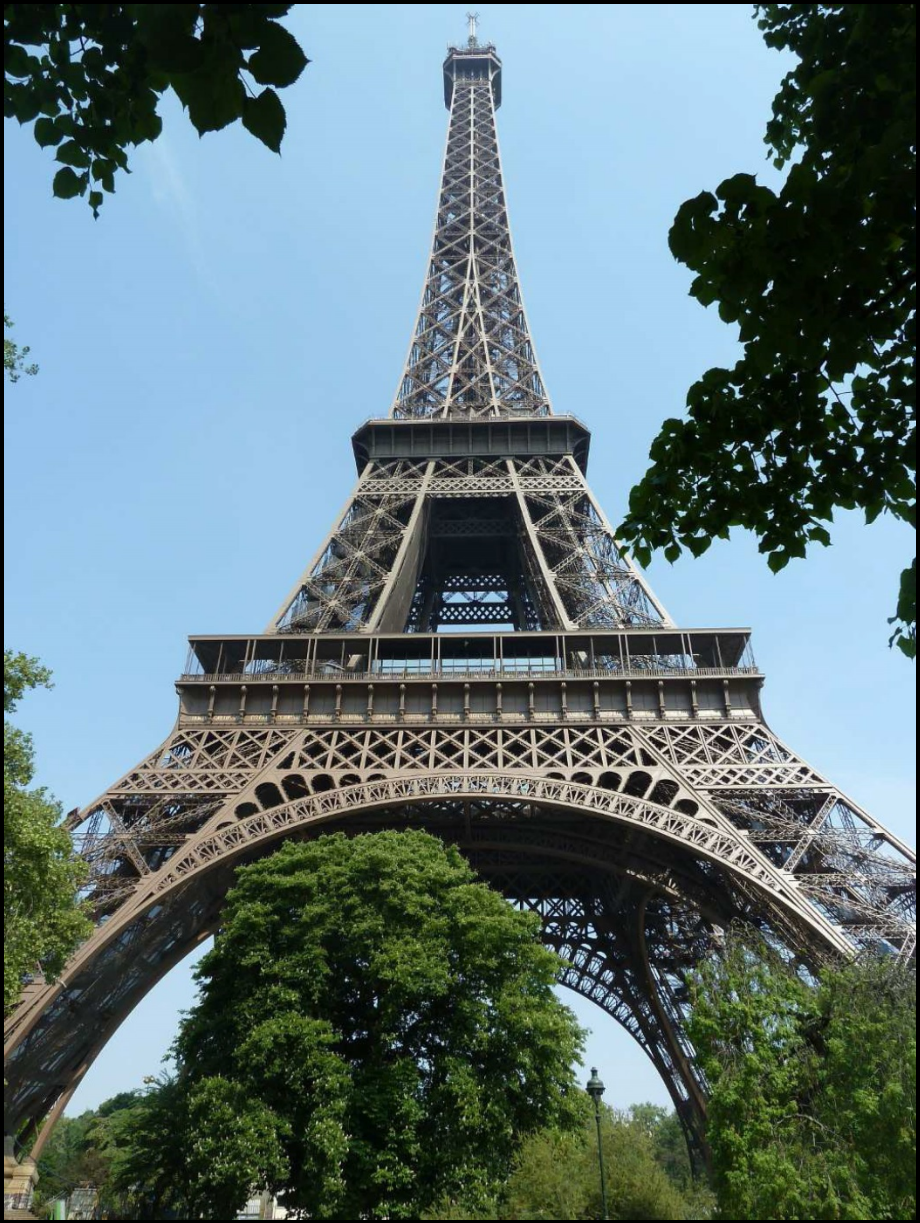
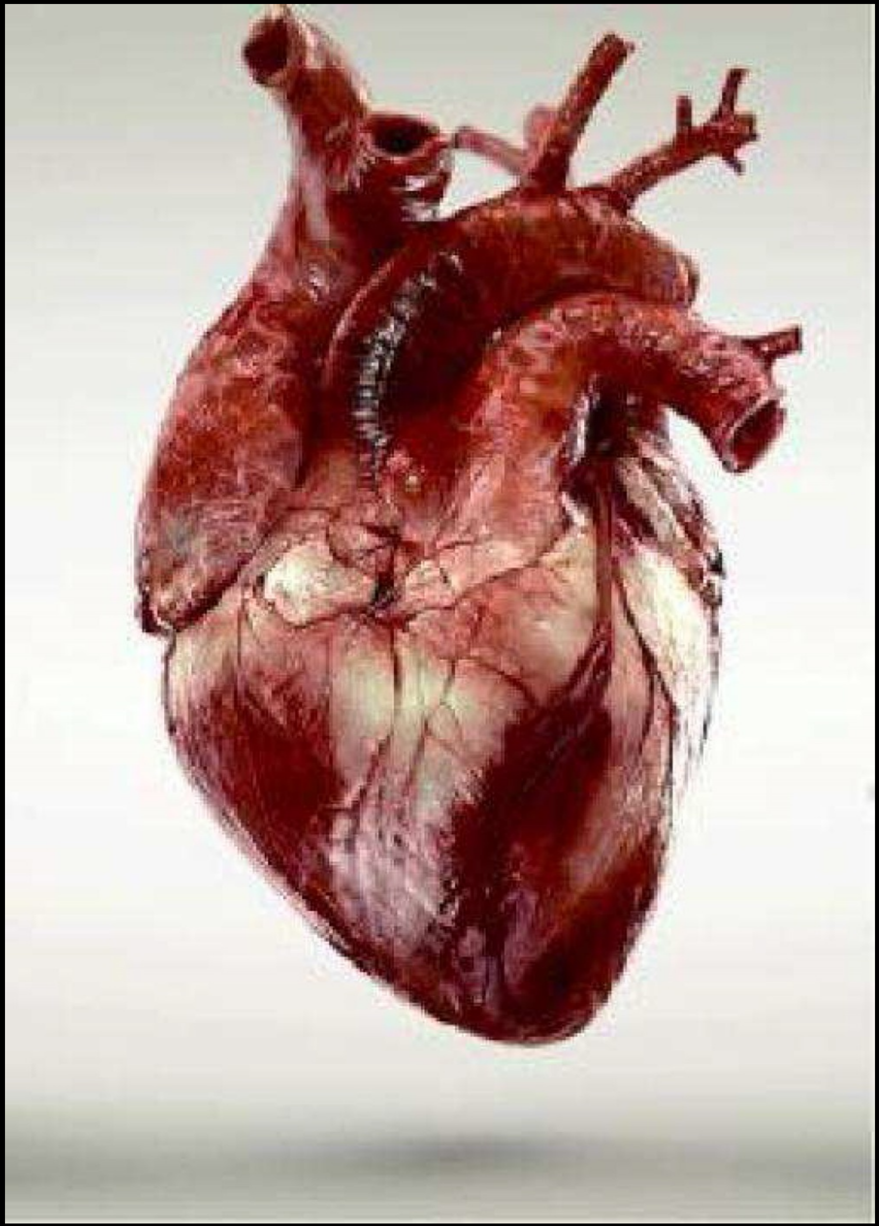
ARToolKit marker

ARToolKit Video

- Augmented Reality by Hitlab
  - https://www.youtube.com/watch?v=ZKw_Mp5YkaE

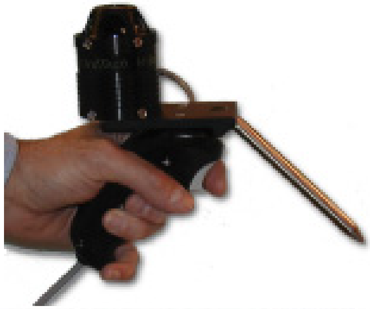
Augmented Reality

- Android app:
  - Download “Augmented Reality Try it Free” by CreativiTIC from Google Play Store
  - App uses Vuforia from Qualcomm for image recognition
- Then point at images on next slide

Optical Tracking: HiBall

- HiBall-3100 tracker system, distributed by 3rd Tech
- Developed within wide-area tracking research project 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

Ultrasonic Tracking

- Systems measure duration of an ultrasound signal to reach microphones.
- InterSense system uses combination of ultrasound and gyroscope.

Logitech 3D Mouse

InterSense IS-900 tracker

InterSense IS-900 Wand

Hybrid Devices: Haptic Feedback Devices

Immersion CyberForce

- PHANToM haptic device
- Force feedback joystick
- Exoskeleton-like devices

LEXOS: Frisoli et. al., Italy

Microsoft force feedback joystick

SensAble PHANToM

Tracking Devices: Bend-Sensing Gloves

- CyberGlove, 5DT
- Reports hand posture
- Gesture:
  - single posture
  - series of postures
  - posture(s) + location or motion

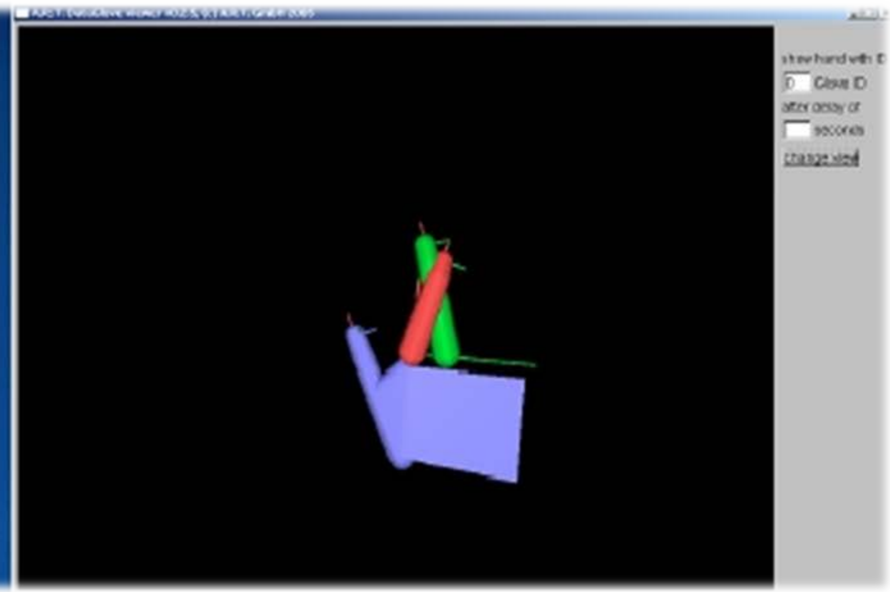
Pinch Gloves

- Determine if two or more fingertips are touching
- Use conductive cloth to close circuit
- Tethered to controller box
- Designed for pinching and grabbing gestures
- Recognize any gesture of 2 to 10 fingers touching, plus combinations of gestures
- Had problems with reliability

www.fakespacelabs.com

Optical Finger Tracking

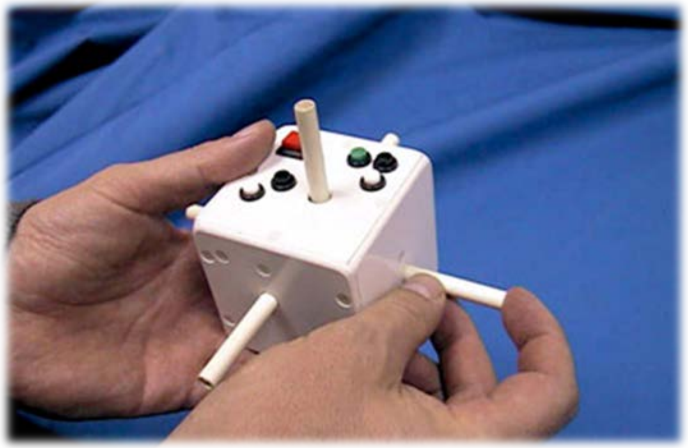
- Extension of ART system
- Tracks three fingers and the hand



Optical Finger Tracking

- Oblong Industries g-speak
  - Video: http://www.youtube.com/watch?v=9OpmxbPzDM0

Special Purpose Device: Cubic Mouse



- Developed at Fraunhofer Institute by B. Frohlich and J. Plate
- Cube shaped box with three rods represents a physical coordinate system
- 6DOF tracker is inside cube
- Rods used to manipulate x-, y-, and z- coordinates of an object (built for controlling cutting planes)
- Target application area: volume rendering for oil and gas industry

Cubic Mouse Video

- http://www.youtube.com/watch?v=1WuH7ezv_Gs

Application-Specific Devices

- Virtual hang-gliding over Rio de Janeiro (L. Soares at. al.)
- Virtual canoe, Siggraph 2005
  - Real-time water simulator with pre-computed 3D fluid dynamics
  - Creates realistic wakes and force feedback of water resistance

Cave Painting

- Physical props (brush, color palette, bucket) allow intuitive painting
- System created by Daniel Keefe at Brown University (now Prof. at Univ. of Minnesota)

Cave Painting Video

- http://www.youtube.com/watch?v=WQv-LnHrmwU

3D Input Devices for Games

Nintendo Wiimote

PlayStation Move

Microsoft Kinect

Leap Motion

Razer Hydra

The Wiimote

- Uses Bluetooth for communication
- Senses acceleration along 3 axes
  - Used for sports games (tennis, bowling, etc.)
- 128x96 pixel monochrome camera with built-in image processing, requires sensor bar
  - Enables 2D on-screen pointer
- Standard buttons and trigger
- Provides audio and rumble feedback
- Up to 4 Wiimotes can be active simultaneously
- Connector for attachments
  - Nunchuck
  - Wii Zapper
  - Wii Wheel


Wii Wheel


Wii Zapper


Sensor Bar

The Wii Motion Plus

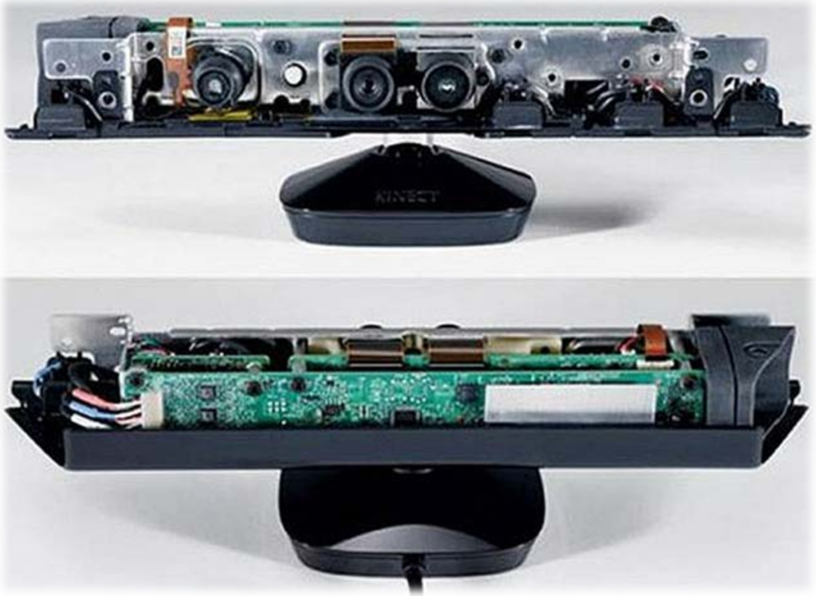
- Initially (June 2009) optional add-on, later built-in
- Uses 3-axis gyroscope
- Captures relative 3D orientation
- Improves pose and motion estimation
- Information captured by gyroscope can be used to distinguish true linear motion from accelerometer readings

Microsoft Kinect

- Microsoft sold 8 million units in first 60 days on market
  - Guinness World Record for "fastest selling consumer electronics device"
- Kinect features
  - RGB camera
  - Depth sensor
  - Microphone array
  - Motorized tilt
  - Connects via USB
- Enables controller-less user interface
- Full body tracking possible
- 2 versions:
  - Xbox (~$100)
  - Windows PC (~$200)

Kinect – Hardware Details

- RGB Camera
  - 640 x 480 RGB pixels at 30Hz
- Depth Sensor
  - 640 x 480 monochrome pixels with 11-bit depth CMOS sensor at 30 Hz
  - Field of view: 57 ° horizontally, 43° vertically
  - Infrared laser projector
  - 4-11 feet range, down to 16 inches in near mode (Windows version only)
- Multi-array mic
  - Four microphones
  - Multi-channel echo cancellation
  - Sound position tracking
- Motorized tilt
  - 27° up or down

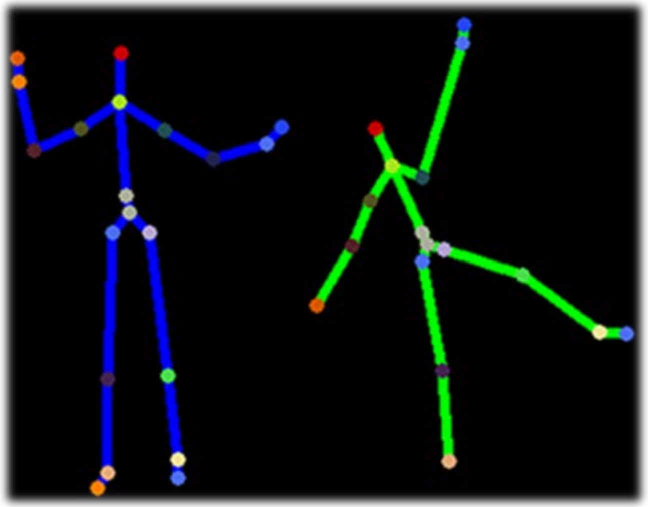


www.hardwaresphere.com

Kinect – Extracting 3D Depth

- Infrared laser projector emits known dot pattern
- CMOS sensor reads depth of all pixels
- Finds location of dots
- Computes depth information using stereo triangulation
  - Normally needs two cameras
  - Laser projector acts as second camera
- Depth image generation

Kinect – Skeleton Tracking



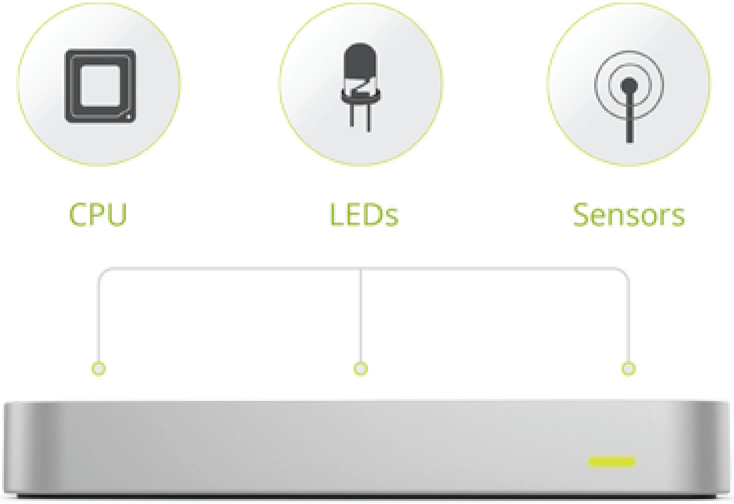
- Combines depth information with human body kinematics
  - 20 joint positions
- Object recognition approach
  - per pixel classification
  - decision forests (GPU)
  - millions of training samples

Leap Motion

- http://www.youtube.com/watch?v=_d6KuiuteIA
- https://www.youtube.com/watch?v=xNqs_S-zEBY

Leap Motion Overview

- Released July 2013
- Small form factor (3 x 1.2 x 0.5 inches)
- Short range finger tracking
  - No access to depth map
- Two IR cameras + optimized image processing
- Inexpensive (~$70)
- Drivers for Windows and Mac OS
- Well documented SDK

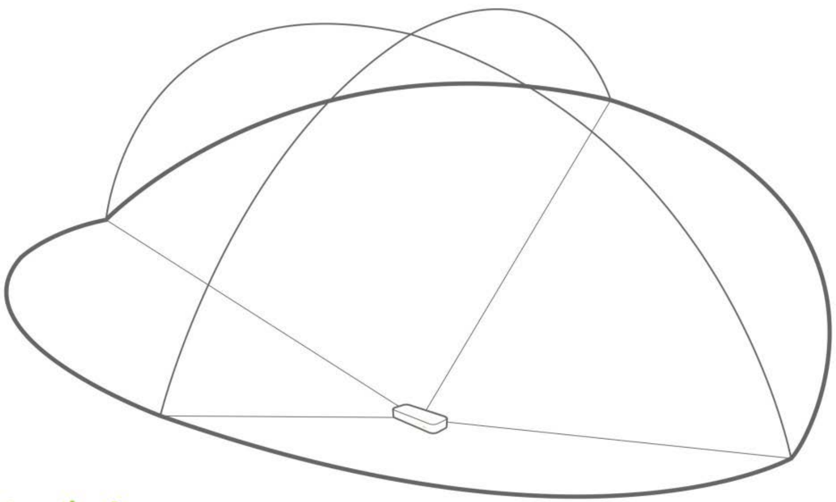


Leap Technology

- 8 cubic feet of interactive space
- 2 cameras
- 3 IR LEDs
- 850 nm wavelength (invisible for the eye)

Leap Tracking

- USB controller reads sensor data into own local memory and performs resolution adjustments
- This data is streamed via USB to Leap Motion tracking software
- Images appear in grayscale
  - Intense sources or reflector of infrared light can make hands and fingers hard to distinguish and track



Interaction Area
2 feet above the controller, by 2 feet wide on each side (150° angle), by 2 feet deep on each side (120° angle)

Oculus Touch

Myo

- Gesture control armband
- Expandable circumference
- Weight: 93 grams
- Thickness: 0.45 inches
- Bluetooth 4.0
- EMG muscle sensors
- Motion sensor
- Haptic feedback (vibration)
- $199

Playstation Move

- http://www.youtube.com/watch?v=hTKpgSpq-8o

PlayStation Move

- Consists of
  - PlayStation Eye camera
  - up to 4 motion controllers
  - Cost for Eye + 1 controller: ~$50
- Features
  - Combines camera tracking with motion sensing
  - 6 DOF tracking (position and orientation)
  - Several buttons on front of device
  - Analog button on back of device
  - Vibration feedback
  - Wireless and USB connectivity

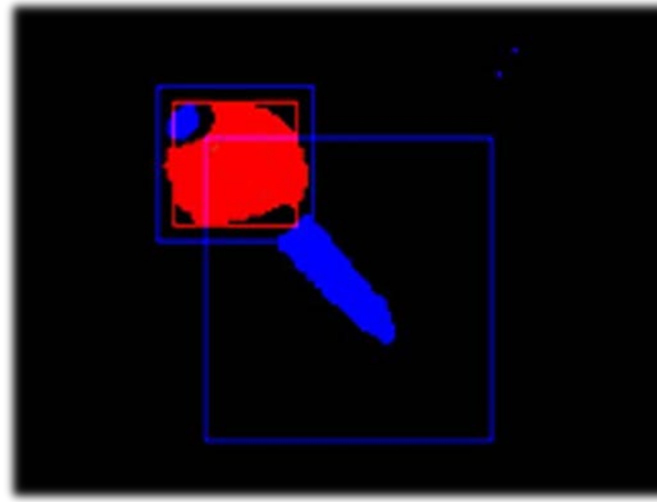
PlayStation Move – Hardware

- PlayStation Eye
  - 640 x 480 (60Hz)
  - 320 x 240 (120Hz)
  - Microphone array (4 mics)
- Move Controller
  - 3-axis accelerometer
  - 3-axis gyroscope
  - Magnetometer: helps to calibrate and correct for drift
  - 44mm diameter sphere with RGB LEDs
    - Used for position tracking
    - Invariant to rotation
    - Provides own light source
    - Color ensures visual uniqueness

www.hardwaresphere.com

PlayStation Move – 6 DOF Tracking

- Image Analysis
  - Find sphere in image with segmentation algorithm
  - Given known focal length and measured size of sphere in image, calculate 3D position
- Sensor Fusion
  - Combines results from image analysis with inertial sensors
    - Accelerometer
      - Gives pitch and roll angles when controller is stationary
      - Gives controller acceleration when orientation is known
    - Gyroscope
      - Measures angular velocity and acceleration



Move Buttons

- Four buttons (Square, Triangle, Cross, Circle) on front
- Two buttons (Select on left, Start on right) on sides
- Big Move button front center
- Small PS button on front with PlayStation Logo
  - Used as power button to switch on the controller
  - Holding it for about 10 seconds will turn off the controller
    - cannot be overwritten by software
- Trigger button on back, can be used as
  - a digital button
  - an analog button with an 8-bit value

Move – Controller

- Accelerometer (16 bit)
  - Kionix KXSC4 10227 2410 (3-axis)
- Gyroscope (16 bit)
  - 2 chips: one for x and y (STM LPR425AL), one for z axis (Y5250H 2029 K8QEZ)
- Magnetometer (12 bit)
  - AKM AK8974 magnetic compass
  - helps to calibrate and correct for drift
- Temperature sensor
- Microcontroller (STM32F103VBT6)
- Bluetooth module (Cambridge Silicon Radio BC4RE), sending 60 updates/sec
- Mini USB connector
- 44mm diameter sphere with RGB LEDs
  - Used for position tracking
  - Invariant to rotation
  - Provides own light source
  - Color ensures visual uniqueness

www.hardwaresphere.com

Move - Camera

- PlayStation Eye
  - 640 x 480 (60Hz)
  - 320 x 240 (120Hz)
  - Microphone array (4 mics)
  - Manual exposure control

Move – 6 DOF Tracking

- Image Analysis
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  - Given known focal length and measured size of sphere in image, calculate 3D position
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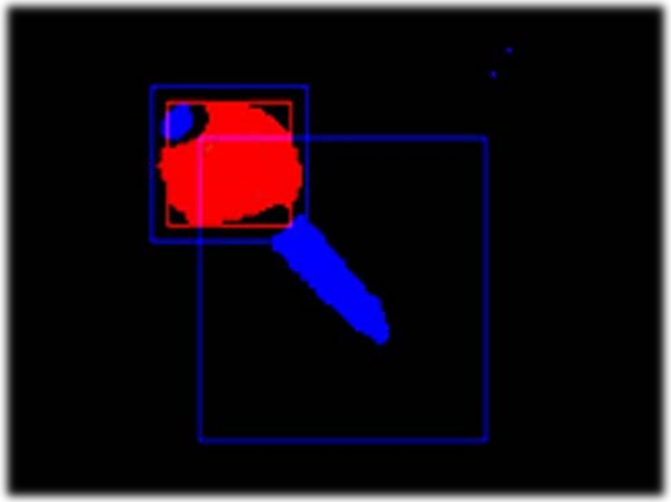
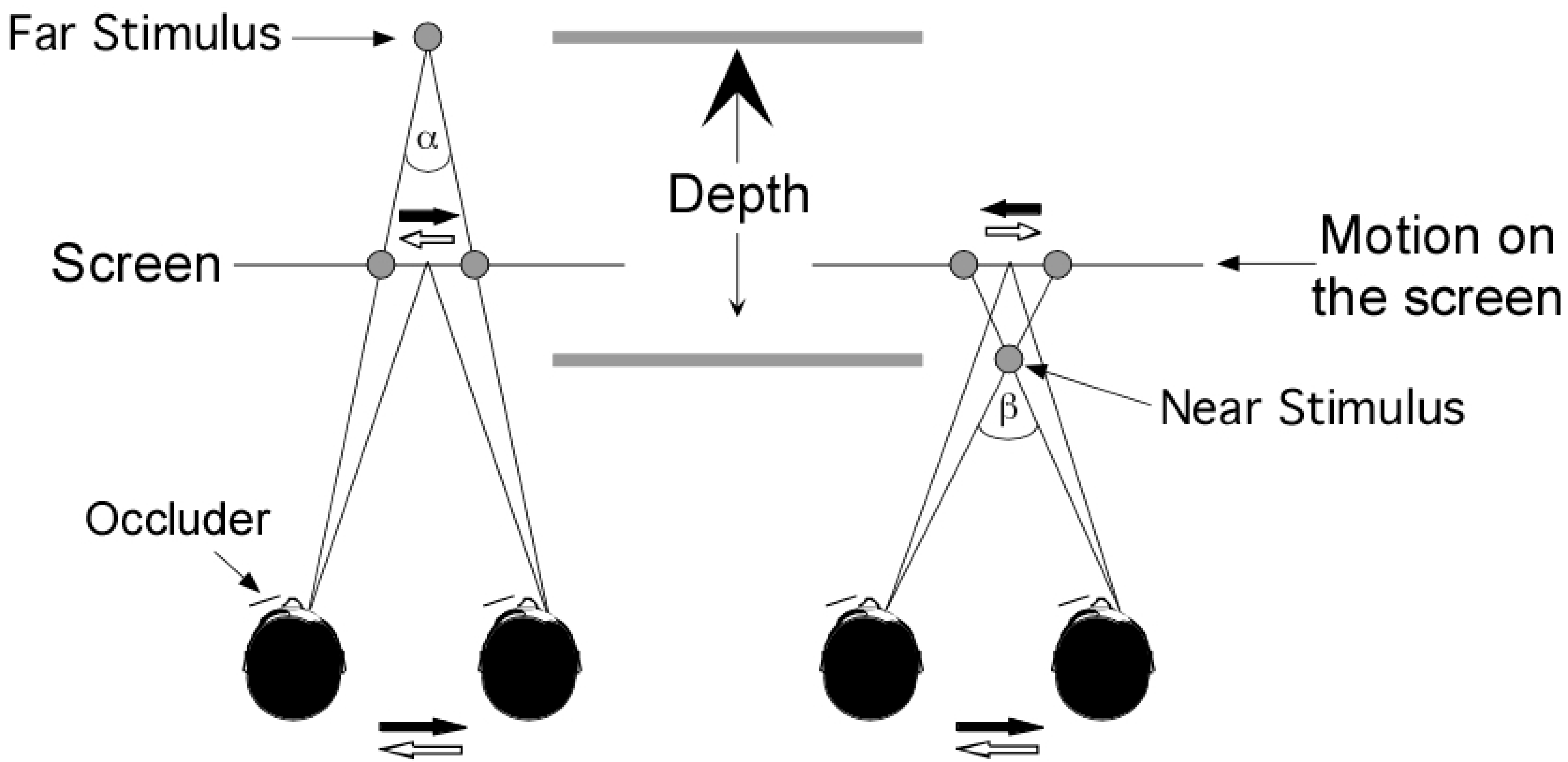


3D Viewing Aids

Overview

- Motion Parallax: move camera
  - For example, oscillate camera between two horizontally offset points.
- Draw 3D grid with fine lines.
- Draw a ground plane and shadows, light source above the scene.
- Monocular depth cues.

Motion Parallax



http://www.yorku.ca/hono/parallax_demo/definition_magnitude.html

3D Line Grid

- Occlusion of data by grid lines reveals depth
- Regular grid with known cell size allows size estimation
- Thin lines: if too thick there might be too much occlusion by the lines

http://www.mymodernmet.com/profiles/blogs/numen-for-use-string-prototype

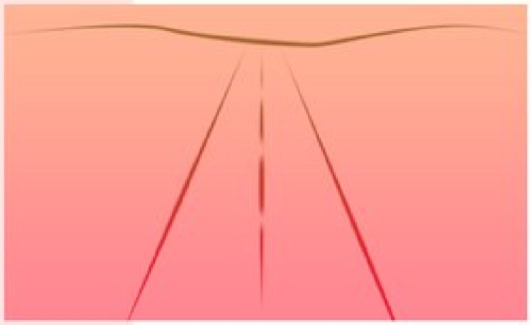
Shadows

http://learnopengl.com/#!Advanced-Lighting/Shadows/Shadow-Mapping

linear perspective

involving parallel lines

Linear perspective is a depth cue that utilizes the fact that lines converge in the distance. That is, **parallel lines** will get "closer together" or **narrower** as they appear **farther** from the viewer. A common illustration of this cue is that of a road or path.



interposition

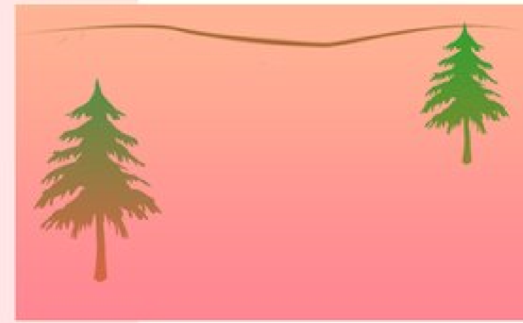
involving overlapping objects

Interposition involves objects that appear to be coming **inbetween** the viewer and another object. If an object is interfering with, or **overlapping** the sight of the second object, it is percieved as **closer** than the second to the viewer.

height in plane

involving separate high and low in the visual field

In a picture, objects that are **further** from the viewer appear **higher** in the visual field. Likewise, **lower** objects suggest that they are **closer** to the viewer. This concept is called **height in plane**.



texture gradients

involving coarse and fine textures

Details are too small to see when they are far away. This idea is known as **texture gradient**. Therefore, areas closer to the viewer will look **coarser**, and areas farther away will have a **finer** texture.

relative size

involving separate objects expected to be the same size

Closer objects appear **larger** than objects further away. Therefore, if two objects are expected to be the same size, then the larger object will appear closer. This is called **relative size**.

light and shadow

involving patterns of light and dark

Patterns of **light** and **dark** can create the illusion of a **three dimensional** figure. This concept can be useful in judging distance.