Winter 2013

# CSE 190: 3D User Interaction

Lecture #5: Input Devices

Jürgen P. Schulze, Ph.D.

# Announcements

- TA: Sidarth Vijay office hours in Sequoiah Hall lab 142:
  - Tuesday and Thursday 11am-1:30pm
- Homework project 2 due Friday February 8th at 1pm

# Calit2 Free Monthly Tour

- Next tour Friday, December 8th, 1-2pm
- Conflicts with homework presentation!
  - On Feb 8th, we will begin grading at 12 noon
- Register at:
  - http://calit2.net/events/popup.php?id=2026

# Virtual Retinal Displays (VRD)

- Send images directly onto the retina
- First invented at the HIT Lab in 1991
- In 1990s, commercially available from Microvision, Inc.
- In principle ideal for many applications

# VRDs – Advantages

- Relatively lightweight
- Potential for high resolution
- Potential for complete visual immersion
- Can achieve good stereo quality (no ghosting)

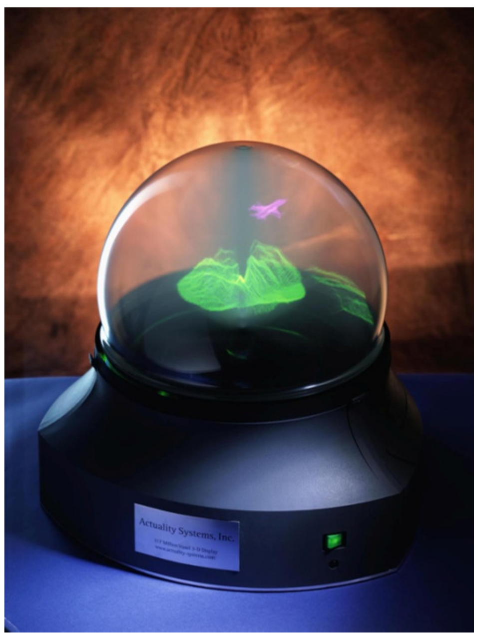
# VRDs – Disadvantages

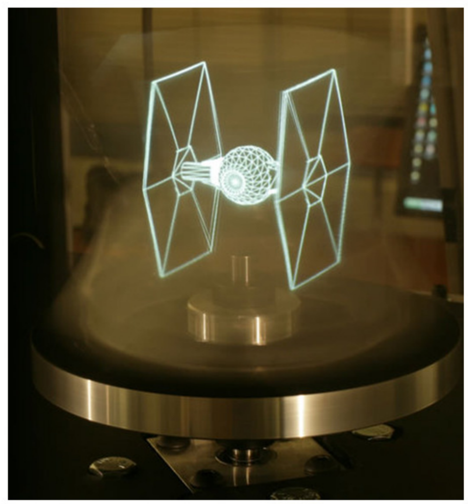
- In reality major deficiencies in many areas
- Low resolution and FOV is small
- Displays are monochrome (red only)
- Eye movement causes problems
- Technology was not commercially viable

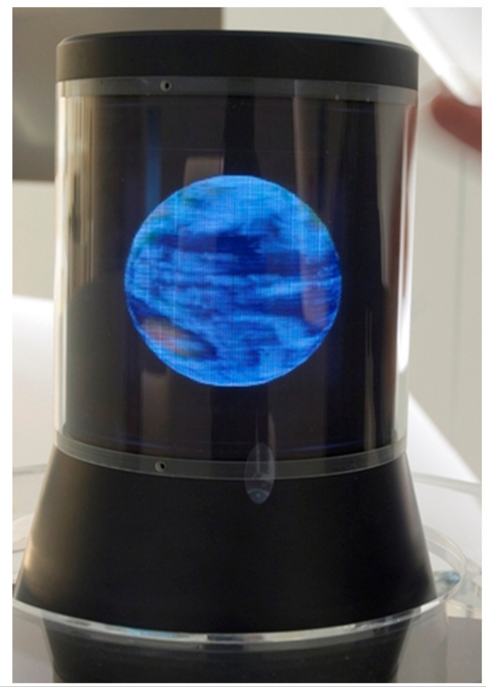
→ Other, theoretically inferior technologies took over in practice

# Auto-Stereoscopic Displays

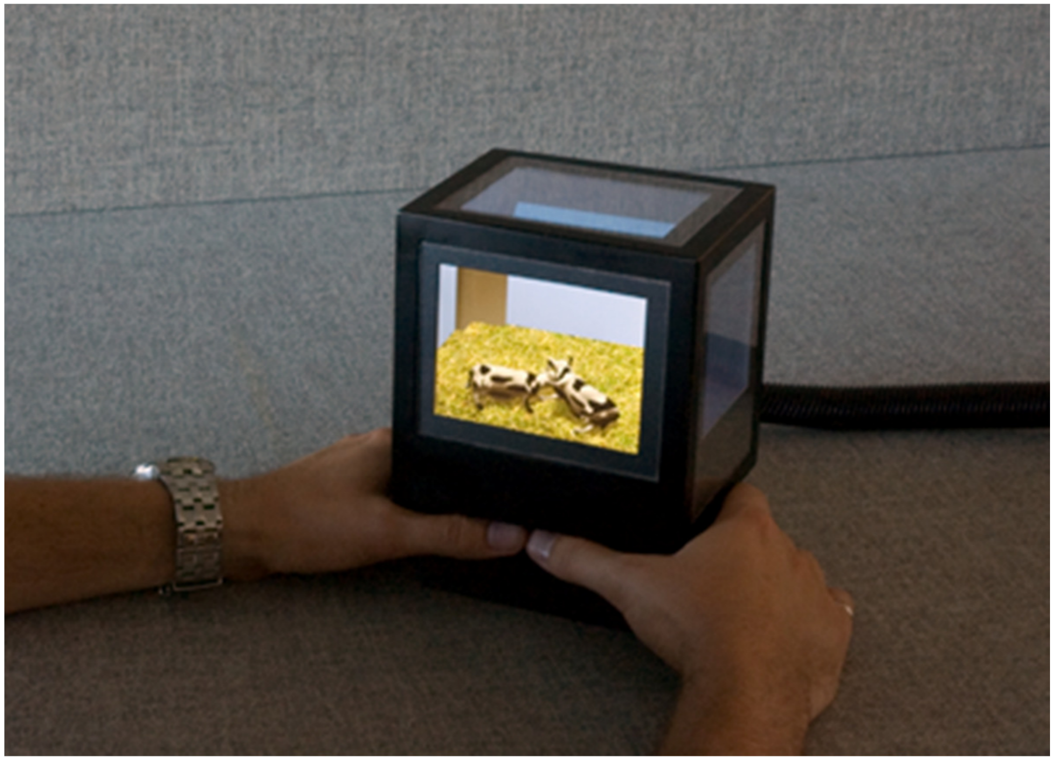
- Lenticular
- Volumetric
- Holographic





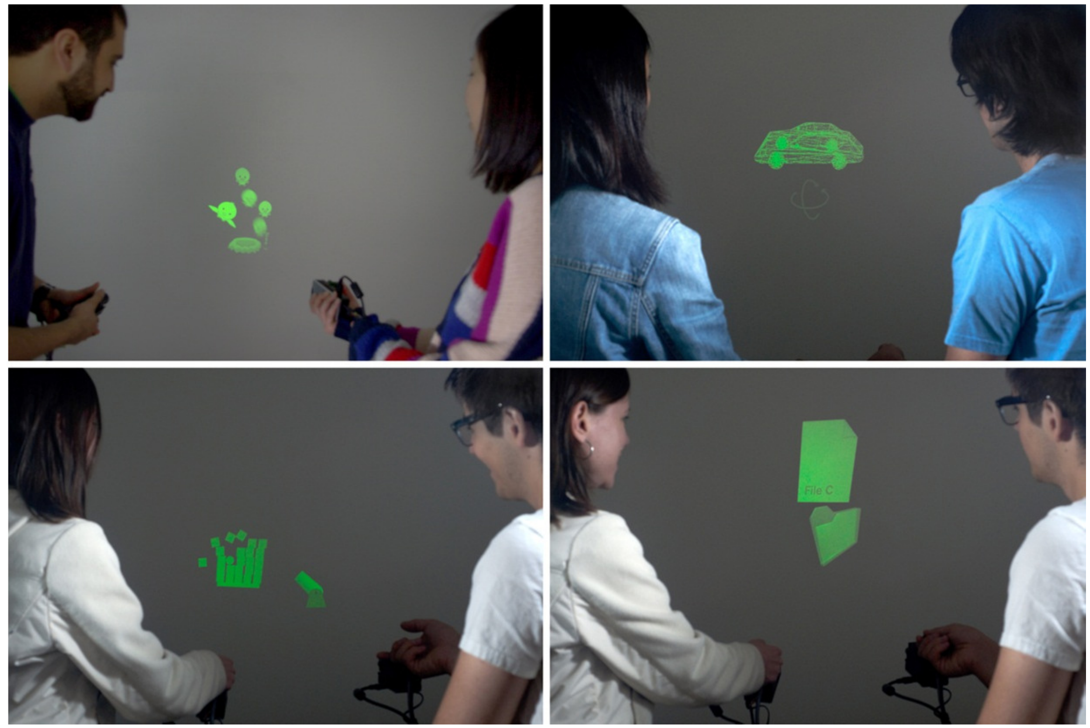


# Simulated Autostereo – pCubee



University of British Columbia
http://hct.ece.ubc.ca/research/pcubee/

# Other Display Technologies



SidebySide/Motion Beam
Disney Research, Pittsburgh

# Which Visual Display to Use?

- Consider lists of pros and cons
- Consider depth cues supported
- Consider level of visual immersion
- This is a very hard question to answer empirically

# 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

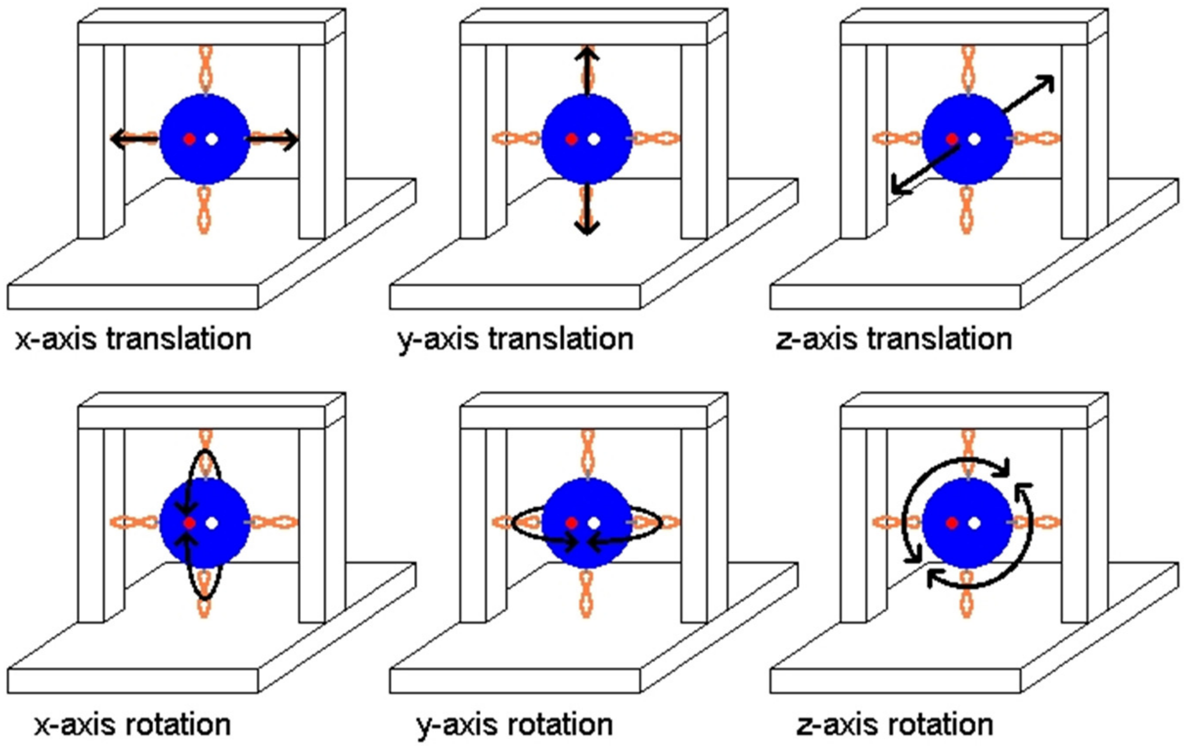
# Degrees of Freedom (DOF)

- 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

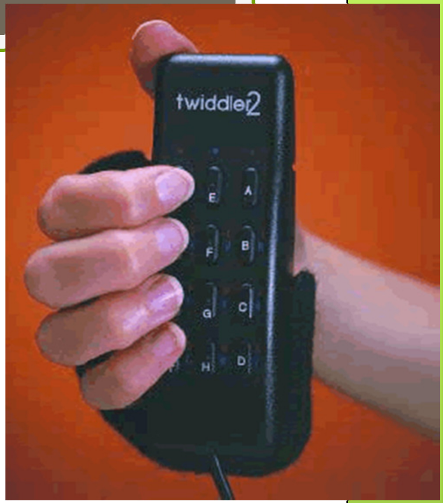
# 3 DOF: GPS

- GPS = Global Positioning Satellite system
- 24 satellites constantly transmit microwave signals of their location
- GPS receivers determine exactly how long it takes for the signals to travel from each satellite
- Receiver needs a signal from at least 3 satellites for accuracy of +/- 100 feet
- Many GPS receivers can improve accuracy by extrapolating additional information
- Tracking accuracy insufficient for VR user interfaces
- Works only outdoors

# 6 Degrees of Freedom



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




- Most popular interaction devices for virtual environments
- Many VR installations are used only with keyboard and mouse. Works well for walk/fly-through presentations to groups

# Desktop Devices: Pen-based Tablets

- Absolute 2D device
- Either direct or indirect

# 6-DOF Relative Devices

- Relative position and orientation
- 3dconnexion/Logitech

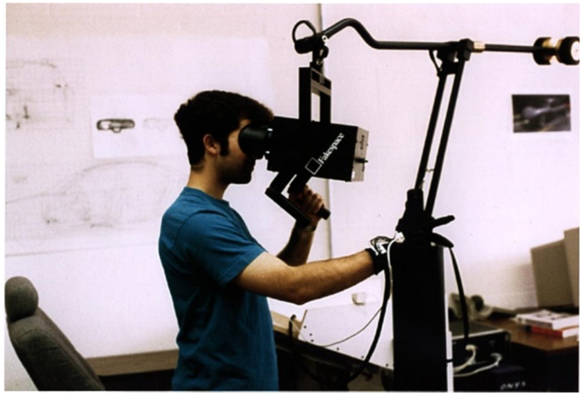
Space Navigator

Spaceball 5000

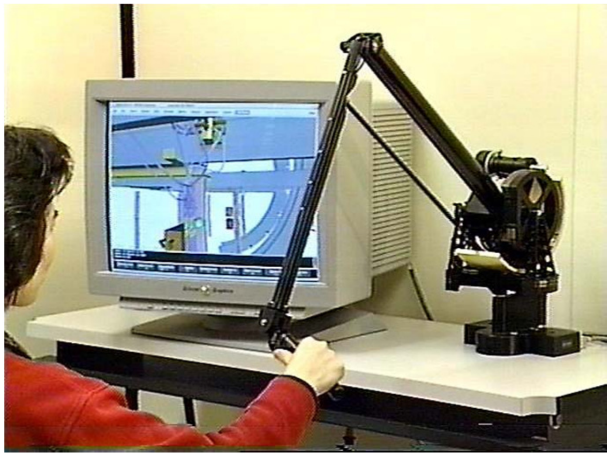

Spaceball

# Mechanical Tracking

- Fakespace Boom: doubles as a stereo display
- Sensable Phantom: doubles as a haptic feedback device



Fakespace Boom



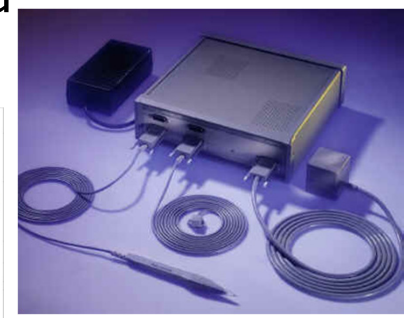
Sensable Phantom

# Electro-magnetic Tracking

- Most commonly used technology
- 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

Wanda

Head/Eye Tracking



Polhemus Fastrak


Ascension Flock of Birds

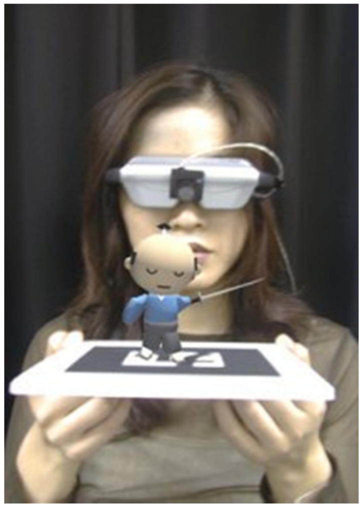
# Inertial Tracking

- Mechanical approach, relying on the principle of conservation of angular momentum.
- Trackers use miniature gyroscopes to measure orientation changes: 3-DOF.
- If full 6-DOF tracking ability is required, they must be supplemented by some position tracking device.
- Gyroscope consists of a rapidly spinning wheel suspended in a housing. Resistance can be measured and converted into yaw, pitch, and roll.
- Inertial tracking devices are fast and accurate, range only limited by length of cable to control computer. Main disadvantage is drift between actual and reported values that is accumulated over time.

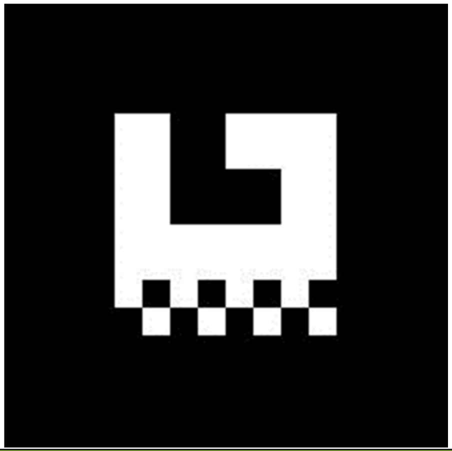

Intersense InertiaCube

# 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 Programming

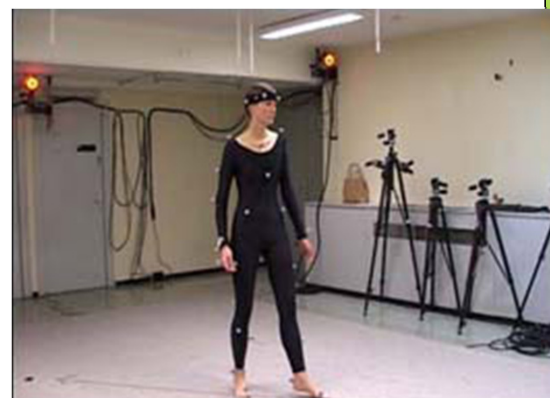
- ARToolkit web site
  - http://www.hitl.washington.edu/artoolkit/
- OSGART: ARToolkit for OpenSceneGraph
  - https://www.artoolworks.com/community/osgart/

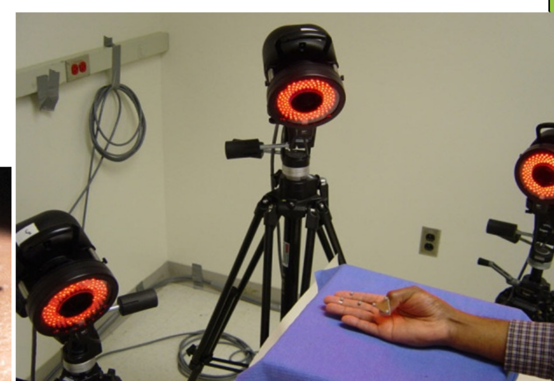
# Video

- Augmented Reality by Hitlab
  - http://www.frequency.com/video/augmented-reality-by-hitlab/2556268

# 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





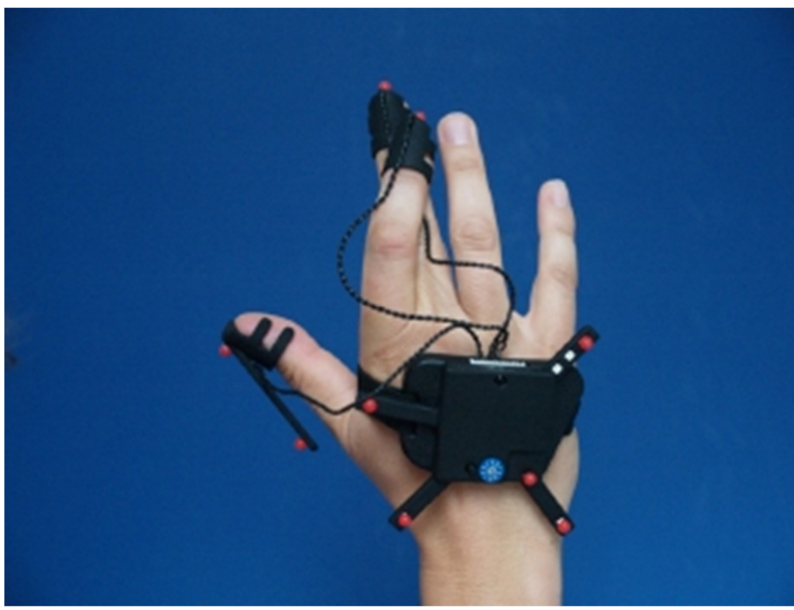
Vicon Tracking System

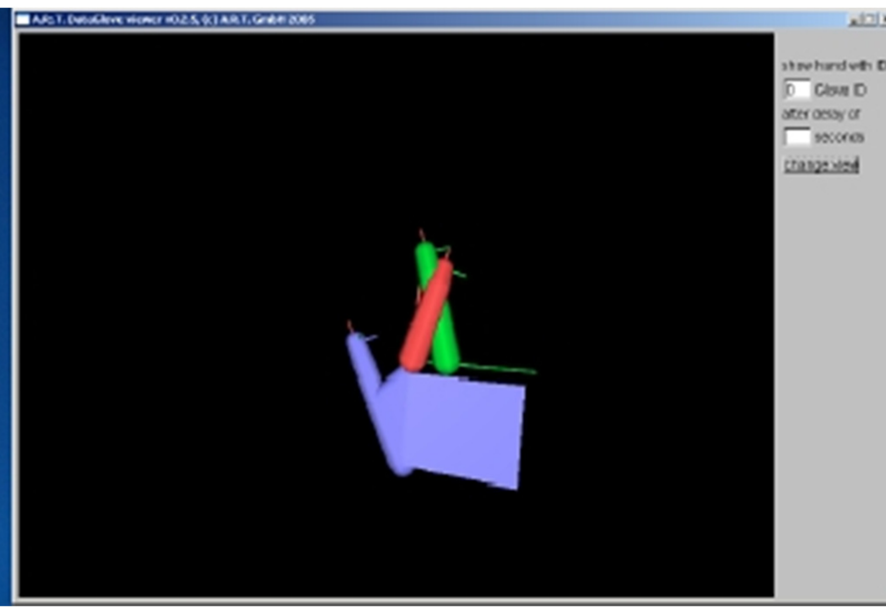
ART Tracking System

Mosquito Aedes Aegypti, carries the dengue virus

# Optical Finger Tracking

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





# Optical Tracking: HiBall

- HiBall-3100 tracker system by 3rd Tech, based on Wide-Area Tracking research project of Department of Computer Science of UNC Chapel Hill
- System is composed of:
  - HiBall Optical Sensor
  - HiBall Ceiling Beacon Arrays
- HiBall Optical Sensor is composed of 6 lenses and photodiodes arranged so that each photodiode can 'view' infrared LEDs in the Beacon Arrays mounted on the ceiling, through several of the 6 lenses.
- Tracker update rate: 2,000 Hz
- No metal or sound interference

HiBall beacon array

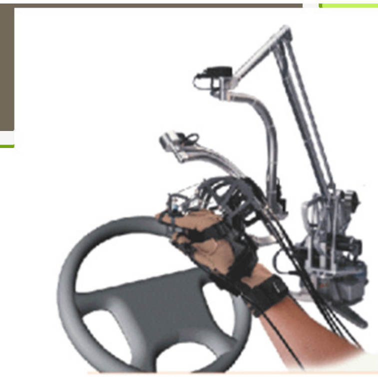
# Ultrasonic Tracking

Intersense

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


Logitech

# Hybrid Devices: Haptic Feedback Devices



Immersion CyberForce

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

LEXOS: Frisoli et. al., Italy

SensAble PHANToM

Microsoft force feedback joystick

# Tracking Devices: Bend-Sensing Gloves

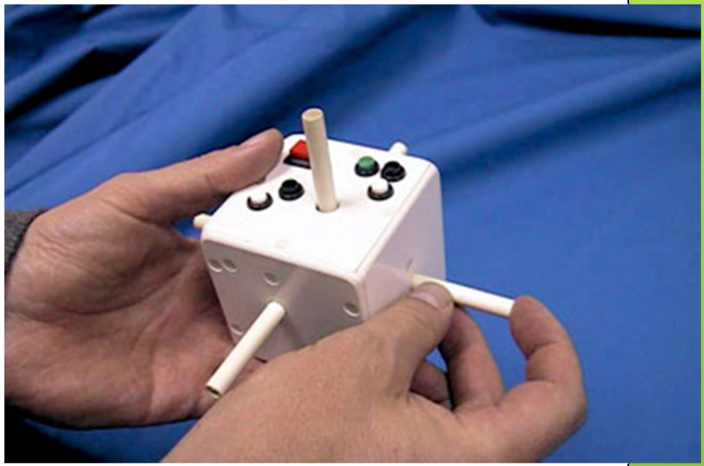
- CyberGlove, 5DT
- Reports hand posture
- Gesture:
  - single posture
  - series of postures
  - posture(s) + location or motion

# Pinch Glove

- 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, plus combinations of gestures
  - Price at the time $2000
  - Had problems with reliability

www.fakespacelabs.com

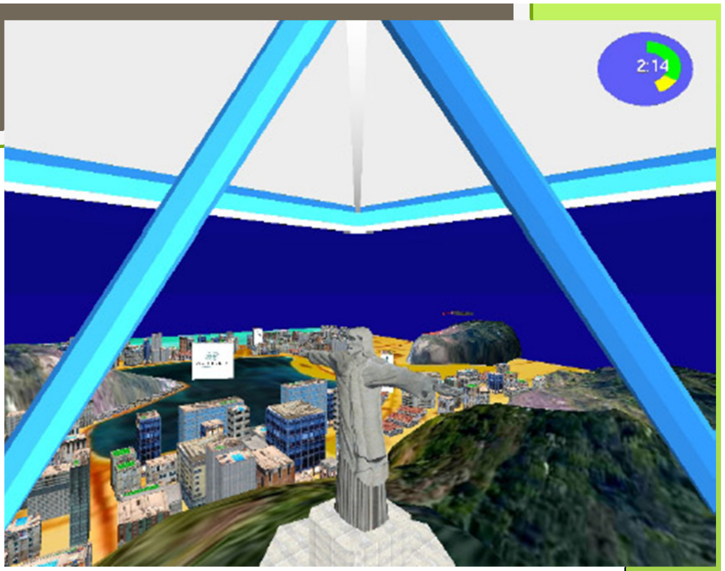
# Special Purpose Device: Cubic Mouse

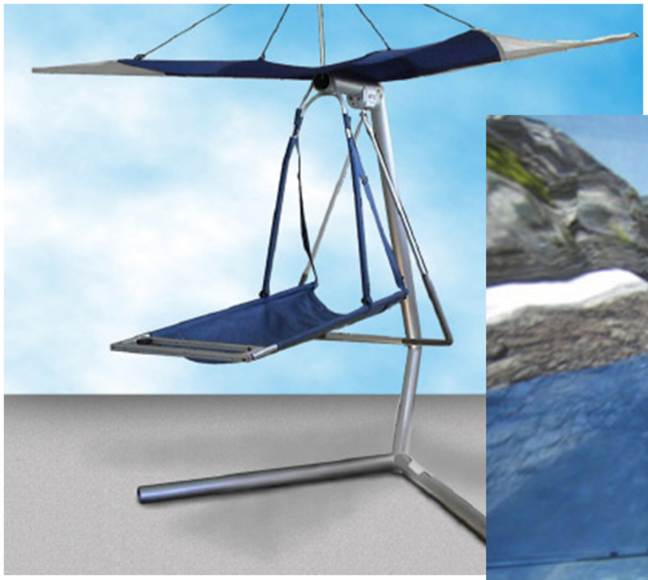


- Developed 1999 at Fraunhofer IMK by B. Frohlich and J. Plate
- Cube shaped box with three rods represents a physical coordinate system prop
- 6DOF tracker is inside cube
- Rods used to manipulate x-, y-, and z- coordinates of an object (for example a cutting plane)
- Major application area: volume rendering for oil and gas industry

# Application-Specific Devices

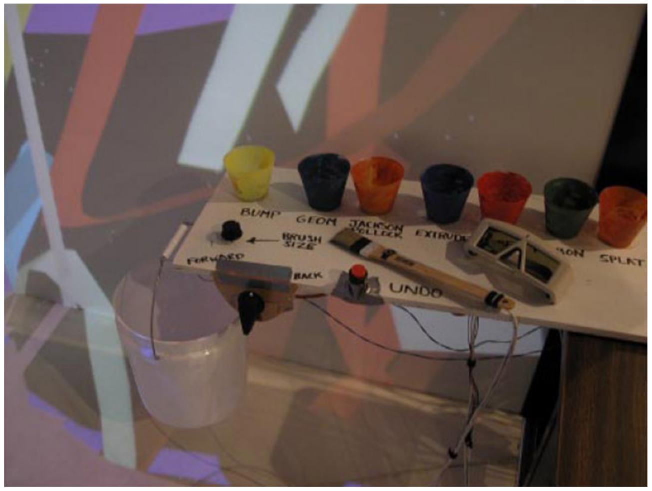
- Virtual Hang-gliding over Rio de Janeiro, L. Soares at. al.
- Virtual canoe, Siggraph 2005: Real-time water simulator with pre-computed database of 3D fluid dynamics. Creates realistic wakes and force feedback of water resistance.

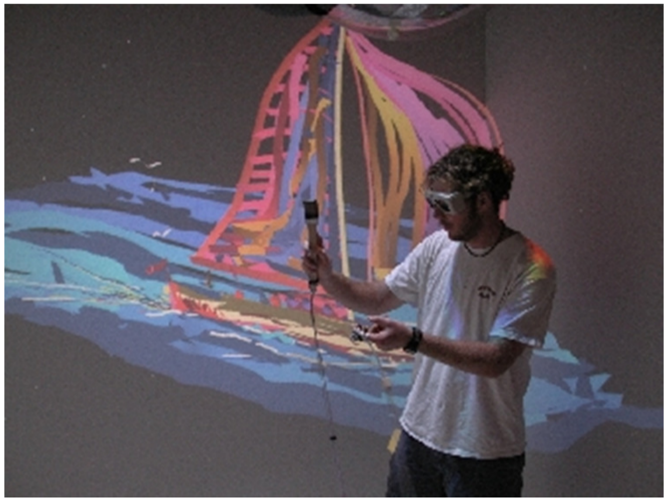




# Cave Painting

- Physical props (brush, color palette, bucket) allow intuitive painting
- By Daniel Keefe, Brown University (now Univ. of Minnesota), ACM Symposium on Interactive 3D Graphics, 2001



# 3D Input Devices Today

PlayStation Move

Nintendo Wiimote


Microsoft Kinect

Leap Motion

Razer Hydra

Gaming devices at consumer prices!

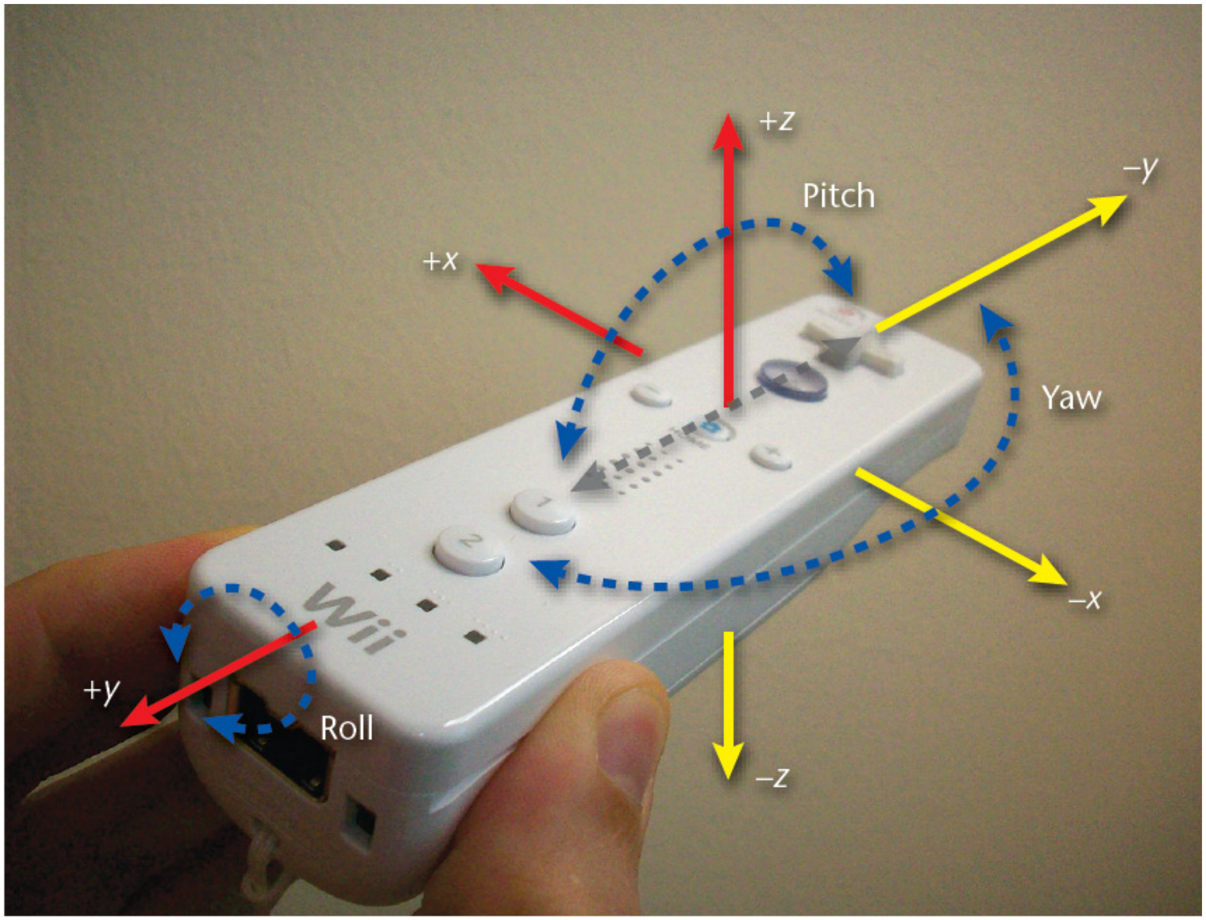
# Video game motion controllers

- Nintendo Wiimote
- Microsoft Kinect
- PlayStation Move

# The Wiimote Device

- Wiimote features
  - Uses Bluetooth for communication
  - Senses acceleration along 3 axes
  - Optical sensor for pointing, with sensor bar
  - Provides audio and rumble feedback
  - Standard buttons and trigger
  - Runs on 2 AA batteries
- Supports two-handed interaction
  - 2 Wiimotes can be active simultaneously

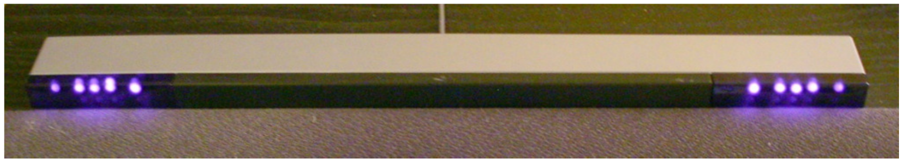
# The Wiimote – Coordinates



# The Wiimote – Optical Data

- Data from optical sensor
  - uses sensor bar
    - 10 LED lights (5 of each side)
    - accurate up to 5 meters
  - triangulation to determine depth
    - distance between two points on image sensor (variable)
    - distance between LEDs on sensor bar (fixed)
  - roll (with respect to ground) angle can be calculated from angle of two image sensor points
- Advantages
  - provides a pointing tool
  - gives approximate depth
- Disadvantages
  - line of sight, infrared light problems
  - only constrained rotation understanding

Sensor Bar



# The Wiimote – Motion Data

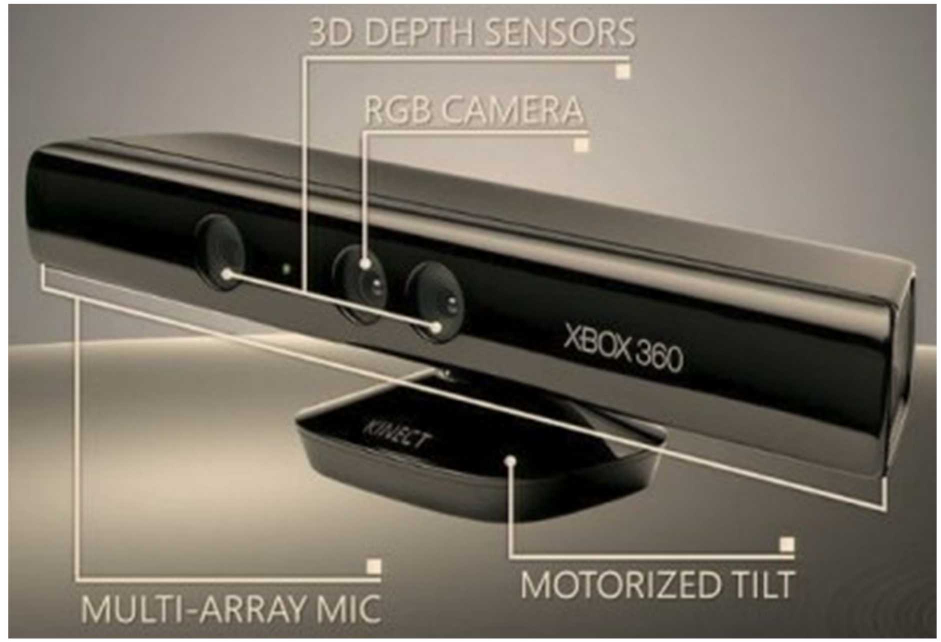
- Data from 3-axis accelerometer
  - senses instantaneous acceleration on device (i.e., force) along each axis
  - arbitrary units (+/- 3g)
  - always sensing gravity
    - at rest acceleration is g (upward)
    - freefall acceleration is 0
  - finding position and orientation
    - at rest – roll and pitch can be calculated ea
    - in motion – math gets more complex
    - error accumulation causes problems
    - often not needed – gestures sufficient
- Advantages
  - easily detect course motions
  - mimic many natural actions
- Disadvantages
  - ambiguity issues
  - player cheating
  - not precise (not a 6 DOF tracker)

# The Wii Motion Plus

- Current Wiimote device
  - gives user useful data
  - not perfect
    - ambiguities
    - poor range
    - constrained input
  - Wii Motion Plus
    - moving toward better device
    - finer control
    - uses dual axis angular rate gyroscope
    - Captures true orientation

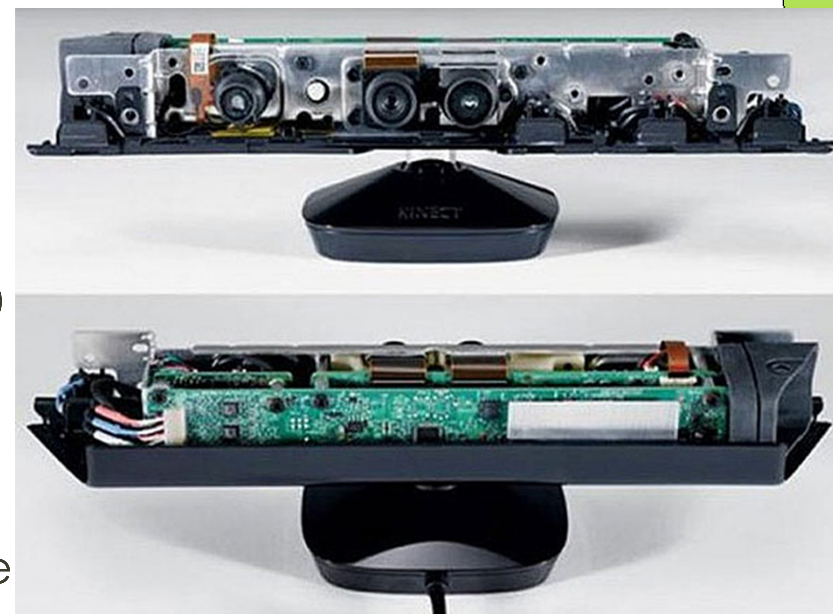
# Microsoft Kinect

- Kinect features
  - RGB camera
  - depth sensors
  - multi-array mic
  - motorized tilt
  - connects via USB
- Supports controller-less interface
- Full body tracking
- 2 versions: for Xbox ($100) and PC ($250)



# Kinect – Hardware Details

- RGB Camera
  - 640 x 480 resolution at 30Hz
- Depth Sensor
  - complimentary metal-oxide semiconductor (CMOS) sensor (30 Hz)
  - infrared laser projector
  - 850mm to 4000mm distance range
  - Windows version has shorter range
- Multi-array mic
  - set of four microphones
  - multi-channel echo cancellation
  - sound position tracing
- Motorized tilt
  - 27° up or down

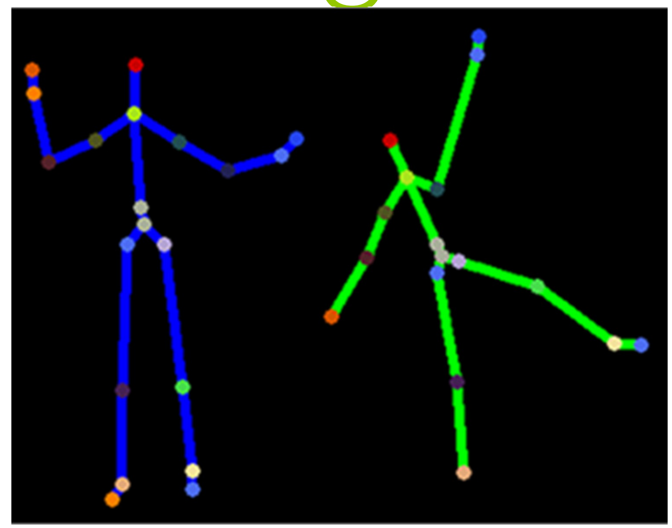



www.hardwaresphere.com

# Kinect – Extracting 3D Depth

- Infrared laser projector emits known dot pattern
- CMOS sensor reads depth of all pixels
  - 2D array of active pixel sensors
    - photo detector
    - active amplifier
- 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

# Kinect Programming

- Two main approaches
  - NITE and Open NI
  - Microsoft Kinect SDK

OpenNI™

# Kinect – Microsoft SDK

- Uses subset of technology from Xbox 360 developer version
- Access to microphone array
- Sound source localization (beam forming)
  - connection with Microsoft Speech SDK
- Kinect depth data
- Raw audio and video data
- Access to tilt motor
- Skeleton tracking for up to two people
- Examples and documentation

# PlayStation Move

- Consists of
  - Playstation Eye
  - 1 to 4 Motion controllers
  - Eye + 1 controller = ca. $80
- Features
  - combines camera tracking with motion sensing
  - 6 DOF tracking (position and orientation)
  - several buttons on front of device
  - analog T button on back of device
  - vibration feedback
  - wireless

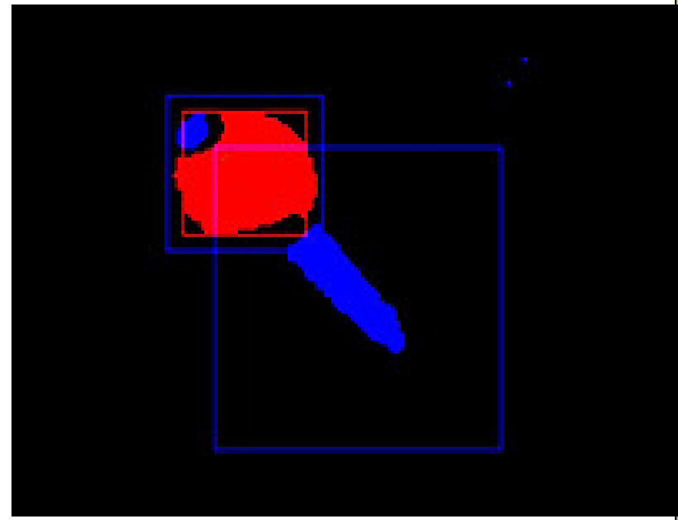
# PlayStation Move – Hardware

- PlayStation Eye
  - 640 x 480 (60Hz)
  - 320 x 240 (120Hz)
  - microphone array
- Move Controller
  - 3 axis accelerometer
  - 3 axis angular rate gyro
  - magnetometer (helps to calibrate and correct for drift)
  - 44mm diameter sphere with RGB LED
    - used for position recovery
    - invariant to rotation
    - own light source
    - color ensures visual uniqueness


www.hardwaresphere.com

# PlayStation Move – 6 DOF Tracking

- Image Analysis
  - find sphere in image
    - segmentation
      - label every pixel being tracked
      - saturated colors more robust
    - pose recovery
      - convert 2D image to 3D pose
      - robust for certain shapes (e.g., sphere)
  - fit model to sphere projection
    - size and location used as starting point
    - 2D perspective projection of sphere is ellipse
    - given focal length and size of sphere, 3D position possible directly from 2D ellipse parameters

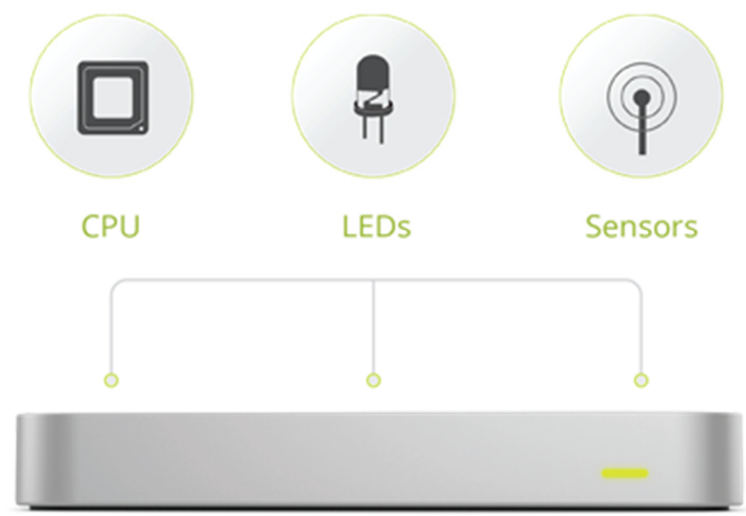


# PlayStation Move – 6 DOF Tracking

- Sensor Fusion
  - combines results from image analysis with inertial sensors (Unscented Kalman Filter)
  - contributions
    - camera – absolute 3D position
    - accelerometer
      - pitch and roll angles (when controller is stationary)
      - controller acceleration (when orientation is known)
      - reduce noise in 3D position and determine linear velocity
    - gyroscope
      - angular velocity to 3D rotation
      - angular acceleration

# Leap Motion

- Short range finger tracking
  - To date no access to depth map
- Inexpensive ($70 on pre-order)
- Not yet available (promised for early 2014)
- SDK available today
- Developer units being shipped
- More and more demo videos available



# Video

- Leap Motion promotional video
  - https://www.leapmotion.com/