# 3D User Interface Hardware

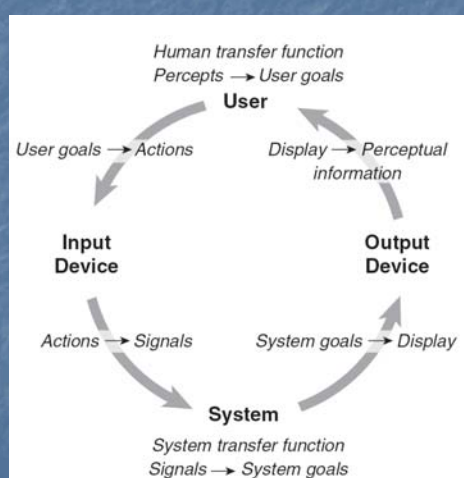
Lecture #7: Input Devices

Spring 2017

Joseph J. LaViola Jr.



# Interaction Workflow



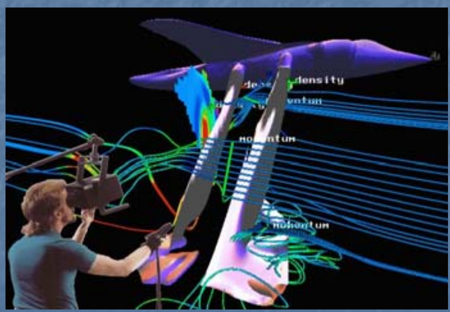
# Lecture Outline

- Input device characteristics
- Traditional input devices (e.g. 2D, Desktop)
- 3D spatial user input devices
  - active sensing
  - passive sensing
  - hybrids
  - 3D mice
- Other devices
- Speech and Brain
- Building special input devices



# Input Devices

- Hardware that allows the user to communicate with the system
- Input device vs. interaction technique
- Single device can implement many ITs



## Input Device Characteristics

- Degrees of Freedom (DOFs) & DOF composition (integral vs. separable)
- Type of electronics: Digital vs. analog
- Range of reported values: discrete/continuous/hybrid
- Data type of reported values: Boolean vs. integer vs. floating point



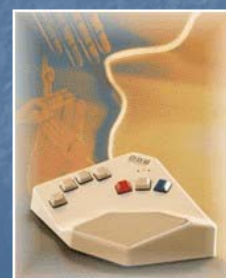
## More Input Device Characteristics

- User action required: active/passive/hybrid
- Method of providing information: “push” vs. “pull”
- Intended use: locator, valuator, choice, ...
- Frame of reference: relative vs. absolute
- Properties sensed: position, motion, force, ...

# Desktop Devices: Keyboards

- Chord keyboards
- Arm-mounted keyboards
- “Soft” keyboards (logical devices)

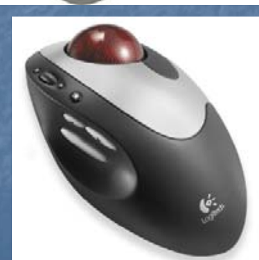
www.virtual-laser-keyboard.com





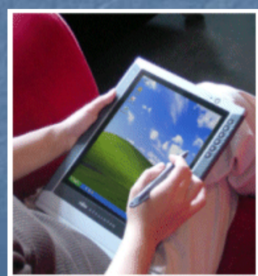
# Desktop Devices: Mice and TrackBalls

- Many varieties
- 2D input to 3DUI
- Relative devices



# Desktop Devices: Pen-based Tablets

- Absolute 2D device
- Either direct or indirect



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# Desktop Devices: Joysticks

- Isotonic vs. Isometric

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# 3D Spatial Input Devices

- Require user's location and/or motion in 3D space
- Data categorization
  - fingers
  - hands
  - full body

Hoffman et al. 2010



# Sensing Devices

- Active sensors
  - user holds device
  - user wears device
- Passive sensors
  - completely unobtrusive (mostly computer vision)
- Strengths and weaknesses for each approach
  - hybrids often used

Image courtesy of http://maxembedded.com

# Active Sensors – Finger Tracking

- Traditional approach – Data gloves


Images courtesy of http://www.cyberglovesystems.com

Image courtesy of http://www.5dt.com



# Active Sensors – Bend-Sensing Gloves

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

# Active Sensors – Pinch Gloves

- Conductive cloth at fingertips
- Any gesture of 2 to 10 fingers, plus combinations of gestures
- > 115,000 gestures



# Active Sensors – Finger Tracking

- Other approaches – wearing vision-based sensors


SixSense
Mistry and Maes 2009


Digits
Kim et al. 2012

# Active Sensors – Finger Tracking

- Other approaches – muscles and skin

EMG Muscle Sensor
Saponas et al. 2010

Skinput
Harrison et al. 2011



# Active Sensors – Hand Tracking

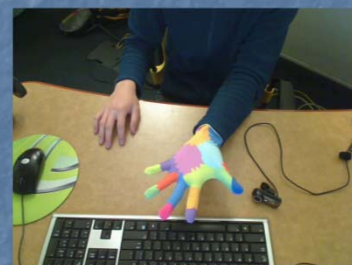
- Sometimes knowing just hand position, orientation or motion is sufficient
- Close relationship with finger tracking
- Two main approaches
  - attach sensing device or reference to hand
  - hold sensing device

# Active Sensors – Hand Tracking

- Approach: attach to hand

Image courtesy of http://www.timelapses.de

Image courtesy of http://spinoff.nasa.gov/Spinoff2005/ch_10.html



Wang and Popovic 2009



# Active Sensors – Position Trackers

- Measure position and/or orientation of a sensor
- Degrees of freedom (DOFs)
- Types of active sensing trackers
  - magnetic
  - mechanical
  - acoustic
  - inertial

# Other for Active Sensing Position Trackers

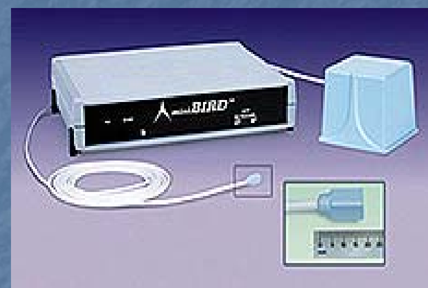
- Most VEs track the head
  - motion parallax
  - natural viewing
- Track hands, feet, etc.
  - "whole body" interaction
  - motion capture application
- Correspondence between physical/virtual objects
  - props
  - spatial input devices



# Active Sensors – Tracking Physical Objects (Props)

# Active Sensors – Magnetic Trackers

- Example: Razer Hydra
- Advantages
  - good range
  - no line of sight issues
  - moderately priced
- Disadvantages
  - metal or conductive material will distort the magnetic field
  - magnetic field can interfere with nearby monitors





# Active Sensors – Mechanical Trackers

- Example: Fakespace BOOM tracker
- Advantages
  - low latency
  - very accurate
- Disadvantages
  - big and bulky
  - usually only one sensor
  - reduced mobility
  - expensive

# Active Sensors – Acoustic Trackers

- Example: Logitech Fly Mouse
- Also known as ultrasonic tracking
- Advantages
  - no interference with metal
  - relatively inexpensive
- Disadvantages
  - line of sight issues
  - sensitive to certain noises



# Active Sensors – Inertial Tracking

- Example: InterSense IS300, Wiimote
- Advantages
  - no interference with metal
  - long range
  - no need for transmitter
- Disadvantages
  - subject to error accumulation
  - only track orientation

# Active Sensors – Hand Tracking

- Approach: handheld devices



Image courtesy of http://www.geeky-gadgets.com/




# Active Sensors – Full Body Tracking

- Traditional approach: bodysuits and attachments

Image courtesy of http://www.vicon.com/


Image courtesy of http://www.sixense.com

## Active Sensors – Full Body Tracking

- Humantenna
  - treat body as antenna
  - not precise but provides info on body motion


Cohn et al. 2012

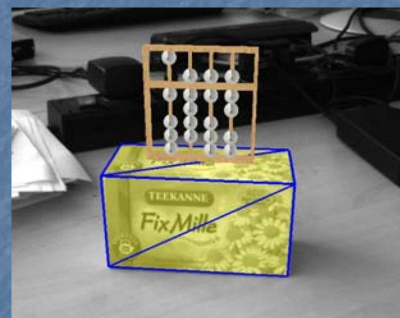


## Passive Sensors

- Makes use of computer vision (also light and sound)
- Unobtrusive – user does not need to wear any special device or clothes
- Typically standard camera or depth camera (finger, hand and body)

# Passive Sensors – Optical/Vision-based trackers

- Exs: Vicon, HiBall, ARToolkit, markerless tracking (SLAM,PTAM)
- Advantages
  - accurate
  - can capture a large volume
  - allow for untethered tracking
- Disadvantages
  - affected by environment
  - occlusion problem





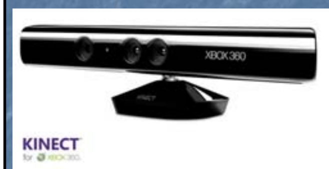

# Passive Sensors – Depth Cameras

- Structured light
  - use a known pattern of light projected into the scene
  - image sensor captures deformed light pattern based on the shapes in the scene
  - extract 3D geometric shapes using the distortion of the projected optical pattern
- Time of flight
  - illuminate it with a beam of pulsed light and calculate time it takes for the light to be detected on an imaging device
- Stereo vision
  - use two calibrated cameras
  - depth for image pixels is extracted from binocular disparity


Image courtesy of http://www.display-central.com

# Passive Sensors – Depth Cameras

- Good choice for body, hand, and finger tracking (depends on resolution and software)




Xbox 360 Kinect
Structured Light

Xbox One Kinect
Time of Flight

Point Grey Bumblebee
Stereo Camera

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# Passive Sensors – Other Approaches

SoundWave, Gupta et al. 2012

LightWave, Gupta et al. 2011

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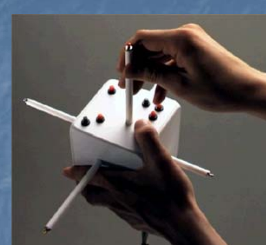
# Active and Passive Sensors – Hybrid Tracking

- Example InterSense IS900, Playstation Move
- Advantages
  - puts two or more technologies together to improve accuracy, reduce latency, etc…
- Disadvantages
  - adds complexity



# 3D Mice

- Ring Mouse
- Fly Mouse
- Wand
- Cubic Mouse
- Dragonfly
- …



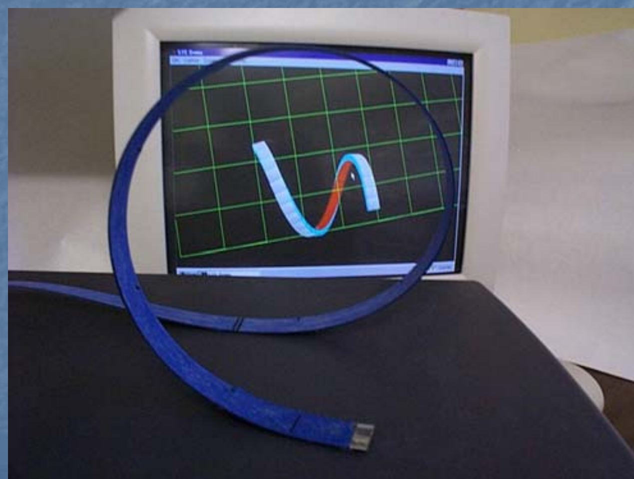
# Desktop-Based 3D Spatial Input

- 6 DOFs without tracking
- Often isometric
- SpaceBall, SpaceMouse, SpaceOrb



# Eye Tracking

# ShapeTape



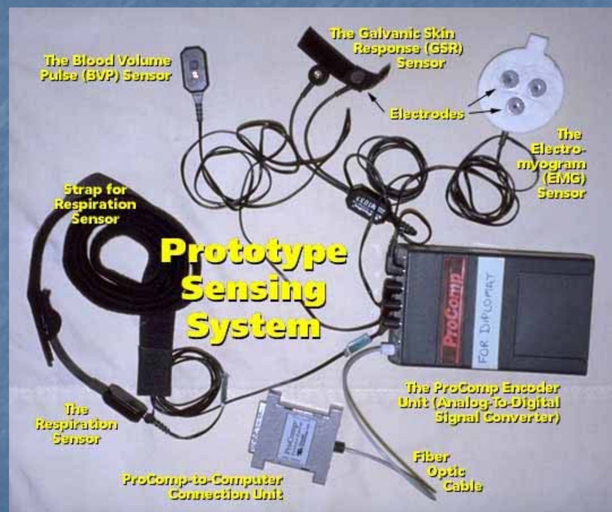


# Speech Input

- Frees hands
- Allows multimodal input
- No special hardware
- Specialized software
- Issues: recognition, ambient noise, training, false positives, ...

http://www.lindamoran.net/images/yelling.jpg

# Affective Sensing Devices






# Brain Input

- Breathing device - OSMOSE
- Brain-body actuated control
  - muscle movements
  - thoughts!

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# Why Build 3D UI Devices?

- Assist in designing new interaction techniques
- Improve upon existing techniques
- Provide interfaces for specific 3D interactions and applications
- Give users more expressive power
- Develop new interaction styles
- Develop new and improved 3D interface hardware
- Fun!!!!

http://www.uni-weimar.de/cms/medien/virtual-reality/research/interfaces/input-device-and-interaction-techniques.html http://www.labri.fr/perso/hachet/CAT/



# Tools of the Trade

- Sensors, buttons, switches, controllers, etc...

www.futurlec.com

## 3D Input Device Building Strategies

- Device function
  - What will the device sense?
    - force
    - motion
    - button presses
  - what physical device types are required?
    - need to choose appropriate sensors
      - digital/analog
      - pressure, bend, potentiometers, thermistors
    - conductive cloth (great sensing material)
- Sensor housing
  - How will sensors be placed in the physical device?
    - physical constraints
    - physical comfort
  - How to build the housing?
    - milling machine
    - vacuform device
    - 3D printer
    - Lego bricks
    - modeling clay



## Device Ergonomics

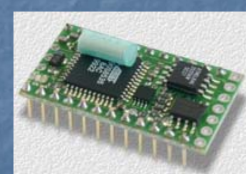
- Good ergonomic design is crucial
  - device housing
  - control types
- Issues to consider
  - device should be lightweight
  - avoid fatigue
  - simple to use
  - easy to reach buttons and controls
  - avoid undue strain
  - don't want to cause user pain

CyberGrasp by CyberGlove Systems

http://www.it.bton.ac.uk/staff/lp22/CS133/haptics.html

# Connecting Devices to the Computer

- Need to connect device to the computer
  - USB
  - serial port
  - Bluetooth
- Often need a microcontroller (not always)
  - small computer that can interface with other electronic components
  - Arduino
  - RasberryPI
  - PIC (www.microchip.com)
  - BasicX-24 -- easy to use
    - programming in Basic
    - has nice development kit
- A typical approach
  - build electronics with prototyping board
  - write code in IDE and download to board
  - test and debug
  - put electronics on circuit board
  - write device driver



www.basicx.com



# Software for the Device

- Need to have software to use device in applications
- Several strategies
  - write driver from scratch
    - need to know something about OS – low level support functions
    - understanding of serial/USB communication protocols
    - typical functions – open, close, read, write
    - plug into API
  - utilize existing software – provide drivers for many devices and machinery to create new ones
    - VRPN – developed at U. North Carolina
    - VRJuggler – developed at Iowa State
  - interface device toolkits
    - Phidgets
    - I-CubeX

# Case Study 1 – Interaction Slippers

- Providing more powerful methods of expression
- Offload functionality to the user's feet
- Input Device
  - pair of commercial house slippers
  - embedded Logitech Trackman Live!™ – wireless trackball
  - conductive cloth
- Allows for toe and heel tapping
- Interact with the Step WIM
  - miniature version of the world place on the floor
  - toe tap to invoke the WIM



# Case Study 2 – Reinventing the Pinch™ Glove

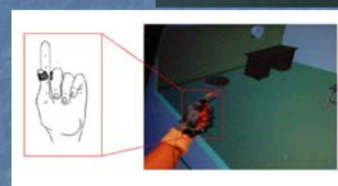
- Pinch Gloves
  - determines of two or more fingertips are touching
  - uses conductive cloth
  - designed for pinching and grabbing gestures
  - at the time $2000
  - had problems with reliability
- Wanted to build custom device
  - less expensive ($200)
  - more flexibility
    - not just pinching gestures
    - plug-n-play
    - allow for a variety of switches

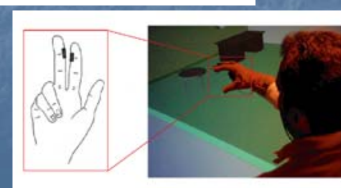
www.fakespacelabs.com

Conductive Cloth Button

# Flex and Pinch Input

- Dealing with input device limitations
  - bend sensing gloves vs. pinch gloves
  - improve existing interaction techniques
- Input Device
  - 16 conductive cloth contacts
  - used with bend sensing glove
  - Can be placed anywhere
- Improve image plane interaction techniques
  - allow user to activate selection with primary hand
  - multiple flex button configurations







# CavePainting Table

- Improve a specific application
  - explore prop-based interaction
  - used for painting 3D scenes
- Input Device
  - tracked paint brush
  - paint cup props
    - uses conductive cloth
  - bucket Tool
  - misc. knobs and switches
- Hold down brush button to paint
- Dip paint brush into paint cups to change strokes
- Use bucket to throw paint

# FingerSleeve

- Inspiration for creating novel interaction techniques
- Pop through buttons
  - use light and firm pressure
- Input Device
  - worn on index finger
  - made from elastic fabric and flexible plastic
  - 6 DOF tracker attached to the back of the sleeve
  - interesting design issues with button style and placement
- Principle
  - light pressure used for temporary action
  - actions confirmed by firm pressure
- ZoomBack Technique
  - temporary and permanent travel
- Snapshot Technique



# Case Study 3 – 3motion

- 3D gesture interaction system
  - developed by Keir et al. 2005, Digital Design Studio, Glasgow School of Art
  - designed as inexpensive tracking solution
  - used for gesture tracking
- Components
  - single chip 3-axis linear accelerometer
  - several buttons
  - wireless bluetooth communication
  - software SDK
- Tested in gaming environment and character manipulator
- Used on cell phone to play virtual golf
- Can you say, "Wii"?

http://research.navisto.ch/publications.html

# From Lab to Production (1)

Chord Gloves

Mapes and Moshell (1995)

Pinch™ Gloves
By Fakespace

Cubic Mouse

Fröhlich and Plate (2000)

Cubic Mouse

By Fakespace



# From Lab to Production (2)

The CAT (Computer Action Table)

Hachet et al. (2003)

www.immersion.fr

The CAT
By
Immersion SAS

HiBall 6D Tracker

Welch (1996)
http://www.cs.unc.edu/~tracker/media/html/hiball.html

http://www.3rdtech.com/HiBall.htm

HiBall
By 3rd Tech

# Prototyping Toolkits – Phidgets

- Phidgets (Greenberg and Fitchett 2001) – building blocks for low cost sensing/control
  - uses USB
  - clean separation of hardware and software
  - simple API
  - Don't need to worry about
    - microprocessors
    - communication protocols
    - soldering
- Variety of sensors
  - touch
  - light
  - force
  - vibration
  - rotation
- Other tools
  - accelerometers
  - switches
  - RFID tags
  - etc...

Analog inputs

Digital Inputs

Digital Outputs

www.phidgets.com



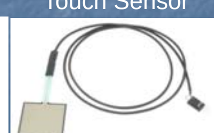
# Prototyping Toolkits – I-CubeX

- I-Cube (Mulder 1995) – uses the Musical Instrument Device Interface (MIDI)
  - MIDI – protocol for communicating control information
  - also uses Bluetooth (wireless)
  - similar advantages to Phidgets
    - no microcontoller programming
    - no circuit design
    - software API
- Variety of Sensors
  - air
  - touch
  - bend
  - temperature
  - magnetic
  - light
  - tilt

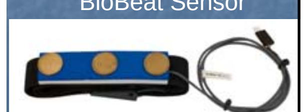
infusionsystems.com

3D Acceleration Sensor

Touch Sensor



BioBeat Sensor



# Next Class

- Selection and Manipulation
- Readings
  - 3DUI Book – Chapter 4