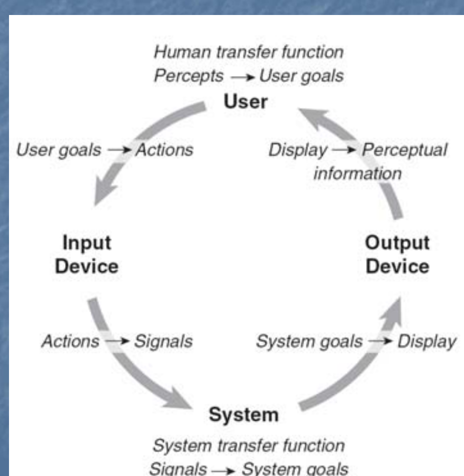
3D User Interface Hardware

Lecture #7: Input Devices

Spring 2016

Joseph J. LaViola Jr.

Interaction Workflow

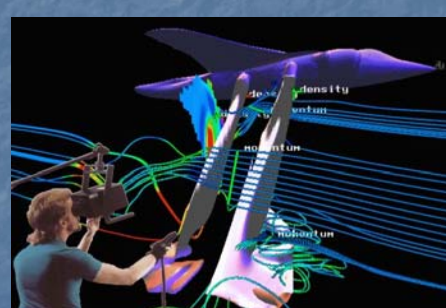


Lecture Outline

- 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

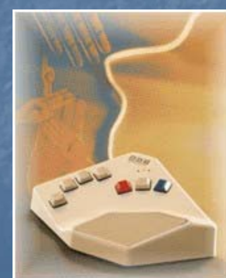
More Input Device Characteristics

- 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

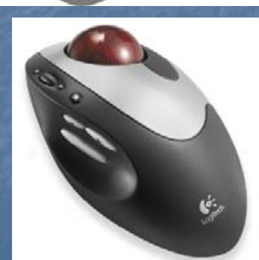
- Chord keyboards
- Arm-mounted keyboards
- “Soft” keyboards (logical devices)

www.virtual-laser-keyboard.com



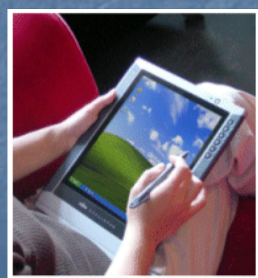
Desktop Devices: Mice and TrackBalls

- 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

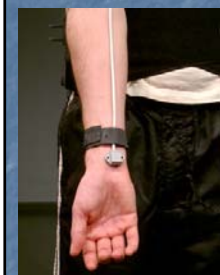
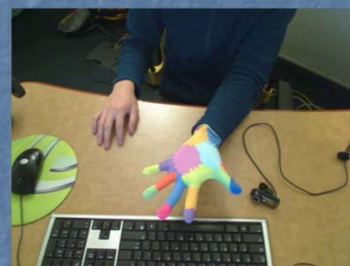


Image courtesy of http://www.timelapses.de

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

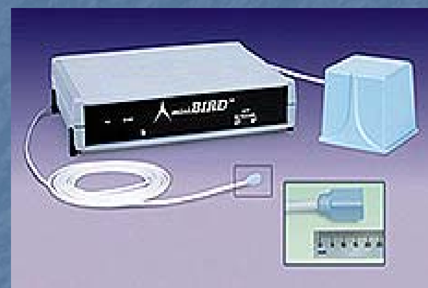
Other for Active Sensing Position Trackers

- 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



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Active Sensors – Mechanical Trackers

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

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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

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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

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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

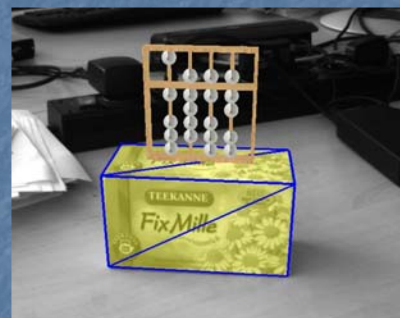
Cohn et al. 2012

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



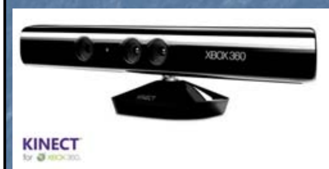
Passive Sensors – Depth Cameras

- 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

Passive Sensors – Other Approaches

SoundWave, Gupta et al. 2012

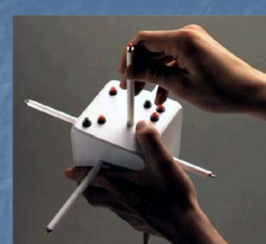
LightWave, Gupta et al. 2011

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
- …

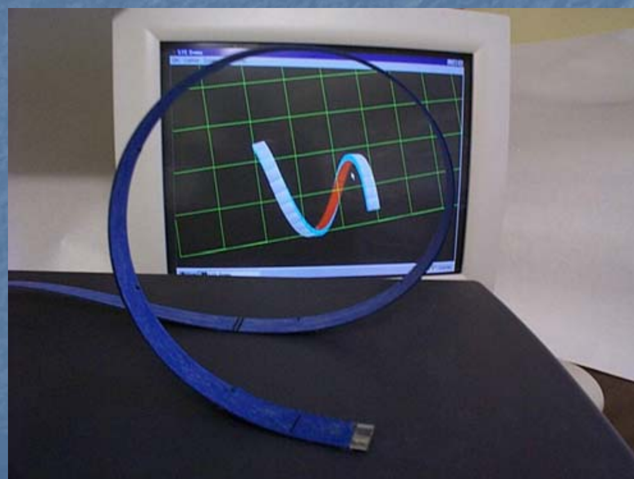


Desktop-Based 3D Spatial Input

- 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

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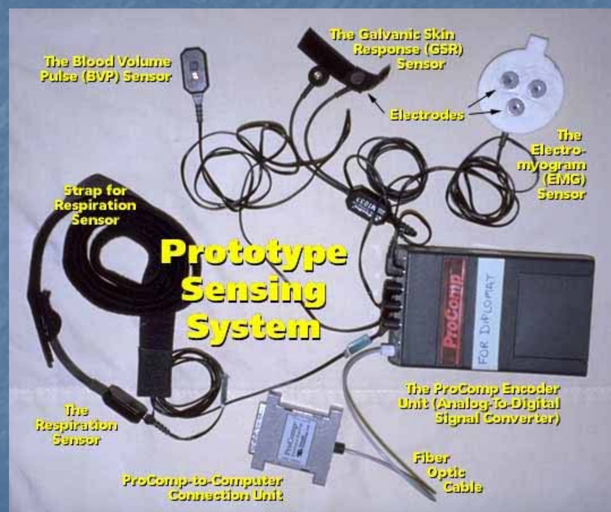
Affective Sensing Devices



Brain Input

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

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

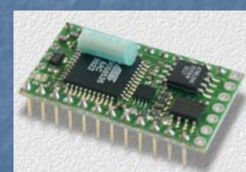
- Good ergonomic design is crucial
  - device housing
  - control types
- Issues to consider
  - device should be lightweight
  - avoid fatigue
  - simple to use
  - easy to reach buttons and controls
  - avoid undue strain
  - don't want to cause user pain

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!^{TM} – 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^{TM} Glove

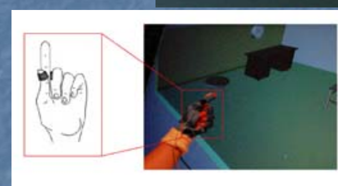
- Pinch Gloves
  - determines of two or more fingertips are touching
  - uses conductive cloth
  - designed for pinching and grabbing gestures
  - at the time $2000
  - had problems with reliability
- Wanted to build custom device
  - less expensive ($200)
  - more flexibility
    - not just pinching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

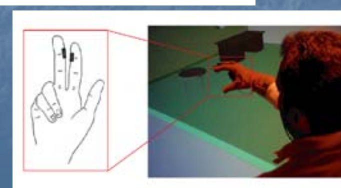
www.fakespacelabs.com

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



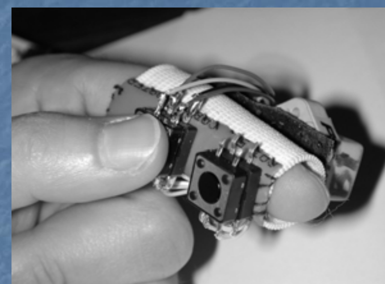


CavePainting Table

- 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)

The CAT
By
Immersion SAS

www.immersion.fr

HiBall 6D Tracker

Welch (1996)

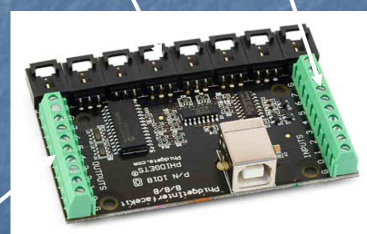
http://www.cs.unc.edu/~tracker/media/html/hiball.html

HiBall
By 3rd Tech

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

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...



www.phidgets.com

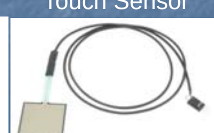
Prototyping Toolkits – I-CubeX

- 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

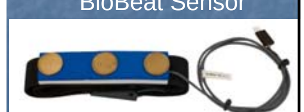
infusionsystems.com

3D Acceleration Sensor

Touch Sensor



BioBeat Sensor



Next Class

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