Interaction Techniques Using The Wii Remote

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May 2008
What is HCI?
Psychology
Understanding People

CS/EE
Understanding Technology

Design
Understanding Needs
Interaction Techniques Using The Wii Remote

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Nintendo Wii

Nintendo’s 5th Video game console
Release Date: 11/19/06
24 million units worldwide (3/31/08)
>24 million Wii remotes
1-4 remotes per console

6-9 million Tablet PCs
Nintendo Wii Remote

Bluetooth HID compatible joystick
MSRP $40 USD

Inputs:
IR camera tracker
Accelerometer
12 digital buttons

Outputs:
Tactile – vibration motor
Auditory – small speaker
Visual – blue status LEDs

Other:
Expansion port
On-board memory
Batteries
IR Camera Tracker

Manufactured by PixArt Imaging
Multi-Object Tracking™ engine (MOT sensor™)

Official specifications are confidential, but….

Hardware IR blob tracking up to 4 points
Resolution: 1024x768 (true: 128x96?)
Refresh Rate; 100Hz
Dot size: 4-bits
Intensity: 8-bits (Full mode)
Bounding Box: 7-bits x-y (Full mode)
Horizontal Field of view: 45 degrees (calc. rad/pixel)
Nintendo Wii “Sensor Bar”

Contains two IR emitter groups

Two dots = 4 values: \((x_1, y_1), (x_2, y_2)\)

4 values → \(x, y, \text{rotation}, \text{and distance}\)

correspond primarily to: \(\text{tilt}, \text{yaw}, \text{roll}, \text{and distance}\)
Accelerometer

Analog Devices (ADXL330)

3-axis linear accelerometer
Range: +/-3g sensitivity
Resolution: 8 bits/axis
Sample Rate: 100Hz
Buttons

Total of 12 digital buttons
11 are accessible to an application

Power button - initiates and terminates Bluetooth connection

Ambidextrous design
4 buttons arranged in a D-pad

Index finger trigger button (B)
Primary thumb button (A)
Output

**Tactile** – Vibration motor, up to 100Hz update rate

**Auditory** – Small speaker, 4Khz*, 4-bit audio streamed from host, approx telephone quality.

**Visual** – Four blue LEDs, player ID, individually addressable, up to 100Hz update rate
Other Features

**Bluetooth** – Broadcom 2042 for Human Interface Devices (HIDs). Not 100% compliant, but compatible with PCs.

**Expansion Port** – Proprietary 6-pin connector. Provides power and Fast I2C communication. Acts as a Bluetooth to I2C bridge.

**Onboard Memory** – device configuration and ~ 5KB of general memory. Physical association of data and identity with a remote.

**Batteries** – two AA batteries provide 20-30 of operation. 8-bit battery level sensor.
Developing Custom Applications

Bluetooth HID joystick compatible with HID driver libraries.

Libraries available for nearly every major development platforms on Windows, MacOS, and Linux.

Visit [http://wiili.org](http://wiili.org) or [http://wiibrew.org](http://wiibrew.org)

I use Brain Peeks C# managed WiimoteLib
Read values from data structure to access data
Most libraries include a sample program

Eventual support:
- Better Event-handling
- Related geometric transformations
- Gesture Recognition
Interaction Techniques
Game Interaction – Pointing

Selection/Navigation

Aiming a weapon/tool

Drawing

Push/Pull or Rotate

Note: All pointing is relative
Game Interaction – Motion

Directional Shake Trigger

Analog Shaking

Tilt Control

Swing Simulation

Games provide context on how to hold remote.
Game Interaction – Buttons and Joysticks

Nunchuk attachment for non-dominant hand

Joystick
2 buttons
3-axis accelerometer

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<th>Analog</th>
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By the Developer Community

- Robot Control
- Synth Music Performance
- Cursor Control
- Flash-Based Mouse Games
Online Videos Tutorials
Moving Stationary

Two dots = 4 values: \((x_1, y_1), (x_2, y_2)\)
4 values → \(\text{tilt}, \text{yaw}, \text{roll}, \text{and } z\)

Moving Stationary

Two dots = 4 values: \((x_1, y_1), (x_2, y_2)\)
4 values → \(x, y, z, \text{and } \text{roll}\)
project 1

Finger and Object Tracking
Finger and Object Tracking

Wii remote can track any IR emitter
Active emitters can be cumbersome
Finger and Object Tracking

Vicon Motion Capture System
Video – Finger Tracking
Object Tracking - Limitations

*Only 4 points* – limitation of Wii remote, but good for the price. Temporal multiplexing, multiple remotes

*No inactive cursor feedback* → 4 point index finger and thumb tracking with pinch detection.

*Arm Fatigue* → Table top or transparent surfaces. Reflective tags may need repositioning.

*Unintentional Reflections* → Active IR emitters when possible. Can be installed in handheld or wearable devices (e.g. sports equipment, animal tracking).
project 2

Interactive Whiteboards
Multi-Touch Interactive Whiteboards

Point Wii remote at display
Map camera coordinates to display coordinates
4-point touch calibration (homography)
Simulate mouse cursor

Effective electronic whiteboard system for $50

>600,000 software downloads (>1.6m views)

Already in use by educators around the world
Number of schools interested in large installations

Tracks up to 4 pens simultaneously.

Most planar surfaces/display technologies
Video – Whiteboard
IR Pens

No resistor will yield about ~130mA
Better to use resistor to run at 100mA
Interactive Whiteboards - Limitations

Maximum 1024x768 resolution. Dependent on good camera positioning. Sensitive to occlusion.

Solutions
Adjust camera position (over-head)
Use multiple Wii remotes
Use rear projected displays.
80% of the way there at 1% of the cost
Everyone

Participants
Two Effects:

1. Increased participation:
   Advances the state of research

2. Increased practicality:
   Advances the state of technology
project 3

Head Tracking for Desktop VR
Head Tracking for Desktop VR

Rigid pair of head-mounted IR emitters yields $x, y, z$ position relative to display

Create motion parallax displays

Sufficient hardware now in millions of homes
6+ major game studios
Head Tracking for Desktop VR

Video – Head tracking
Jeff Dunham and Peanut part 2
From: baddudenorris
Views: 1,540,777
06:46

Head Tracking for Desktop VR Dis...
From: ic1sm
Views: 2,648,640
04:45

Peanut and Jeff # 2
From: brigurl88
Views: 2,641,853
09:53

Jeff Dunham and Walter # 2
From: brigurl88
Views: 1,797,789
09:57

Human-Computer Interaction Institute
Motion Parallax

- Very important depth cue
- Velocity of objects when moving
- Occlusion behavior

[Ware, Arthur, and Booth CHI’93]
Motion parallax is more important than stereo

www.flickr.com/photos/kap_cris/472159801/
Calculating Head Position

Horizontal Position

\[ \theta_{headX} = \text{radsperpixel} \times D_{headX(pixels)} \]

\[ D_{headX} = D_{headZ} \times \tan(\theta_{headX}) \]

Vertical Position

\[ \theta_{head-camY} = \text{radsperpixel} \times D_{head-cameraY(pixels)} \]

\[ \theta_{headY} = \theta_{cam} - \theta_{headY} \]

\[ D_{headY} = D_{headZ} \times \sin(\theta_{headY}) \]

\[ D_{head-displayY} = D_{displayY} - D_{headY} \]
Now we have head X, Y, Z...
Translating the camera

Provides motion parallax, but inaccurate for portal simulation.
Rotating the camera

Provides *some* motion parallax, but **inaccurate** for portal simulation. Image plane moves causing mismatch with lack of display movement.
Off-Center Perspective

Provides **accurate** motion parallax for portal simulation. Image plane is stationary matching lack of display movement. Image axis stays centered through display.
Off-Center Perspective

Reducing head distance increases FOV producing correct window-like behavior.
Off-Center Perspective – near plane

Computing moving boundaries of a near plane that is closer than the spatially locked plane, allows rendering objects floating out in front of the screen.

\[ x' = x \cdot \left( \frac{D_{\text{near}}}{D_{\text{display}}} \right) \]
Head Tracking - Limitations

*Only works for 1 person* – split screen or shutter glasses

*Limited Tracking Volume* – increase field of view with wide angle lens or use multiple remotes.

*Can’t touch objects* – Sorry. Keep objects behind the display surface and blame the display.

*Conflicting Stereo Depth Cues* – weakens the effect, use stereoscopic display technology (polarized/shutter glasses, etc)
Anaglyph (red/blue): bad color fidelity, but would work, cheap

Shutter glasses: active device, frame sync, higher frame rates (120Hz okay)

Polarized glasses: does not work with most existing consumer televisions, cheap

Auto-stereoscopic: not consumer technology yet
If you can’t provide stereo, removing the conflicting stereo depth cues **will improve** the head tracking illusion.
Spatial Augmented Reality
Spatial Augmented Reality

Projected light can be used to augment the appearance of physical objects.

Aligning to static objects can be done manually.
Moving objects requires low-latency, high-resolution tracking.

1024x768 @ 100Hz tracking of the Wii remote is quite good.
Video – Foldable Displays
Spatial Augmented Reality

Wii remote only tracks 4 points.
- Limits the number of objects
- Limits the geometric complexity

4 points can track arbitrary quadrilateral

Assumptions reduces necessary points
- square surface
- constrained to a plane
Spatial Augmented Reality

- If the projection parameters are known, we have epipolar geometry.
- Calculate the projector-camera fundamental matrix.
- Four points of geometric relationship, yields camera pose estimation.
- Registration onto surfaces in 3D space should be possible.
Other ideas...

**3D Motion Tracking** - extension of finger tracking, using 2 or more remotes allow tracking of individual points in 3D space.

**Tracking with ID** – currently no point ID. Use high-speed IR receiver in conjunction with camera should allow location with ID.

**IR Glyphs** – use varying spatial and temporal behavior of 4 IR emitters to create unique IDs. Allows Wii remote to know what object it is pointing at.

**Laser Tag** – instrument each Wii remote with IR emitters so they can see each other. ID can be temporally verified.

**Gesture Recognition** – current use is limited compared to state of the art. Unique challenges in recognizing variations in speed, size, and orientation with either accelerometer or camera data.
Summary

> 24 million Wiimotes
Sophisticated I/O capabilities
  - IR camera, Accelerometer, Buttons
  Vibration, Speaker, LEDs, I2C port
Only $40 USD

Vast number of applications
limited only by creativity

Document & Share
> 8 million views (Youtube)
> 600,000 downloads
1000s of students and teachers
8 patent licensees (in progress)
> 6 major game studios
A few large educational initiatives
Jeff Han – FTIR/Perceptive Pixel

Andy Wilson – Surface/Xwand

Paul Dietz – Diamond Touch/iPhone parent

Bill Buxton – Multi-touch/Maya/Alias

UIST – User Interface Software & Technology
Also consider: SIGGRAPH & SIGCHI
Other Research Work

- Projector-Based Location Discovery and Tracking
- Interaction Techniques using the Wii Remote
- Low-Cost EEG for Task Classification
- Kinetic Typography
- Haptic Pen
- Multi-channel Audio Rendering
- $14 steadycam

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What next?