WiiMoCap: a low-cost motion capture system using the Nintendo Wiimote

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Introduction

We created an inexpensive laboratory motion tracking system using a Nintendo Wiimote, a USB Bluetooth adapter, open-source software and LabVIEW (National Instruments, Inc. Austin Texas).

The system allows for flexible integration with different platforms, and costs less than $200. The system was validated for acquisition rate, delays in acquisition, and accuracy. Our WiiMoCap system's performance was on par with a commercial system orders of magnitude more expensive.

Objective

- General Requirements of the motion capture system:
  - Affordability, reliability, flexibility, and ease of use
- Technical Requirements:
  - Latency in motion capture < 80ms
  - Tracking accuracy < 1cm (within a tracking volume 4ft^2)
  - Acquisition rate > 60 Hz
- The Wiimote optical sensor has a resolution of 1,024 x 768 pixels, transmits position updates at 100 Hz using Bluetooth wireless protocol, and has 45 degree horizontal field of view
  - The Wiimote specifications can meet the above mentioned motion capture system requirements.

Methods: Implementation

An infrared (IR) marker was used to track a subject's arm movements. Two Wiimotes were located at vantage points to minimize occlusion of the IR marker and to provide reliable tracking in the two dimensional (2D) workspace.

Wiimote

Part/Model Numbers

Wii compatible Bluetooth USB devices:
www.wiili.org
(Targus ACB10US or Kensington 33348)

Bluetooth drivers for Windows OS
www.bluesoleil.com

WiimoteLib - Open source lib for Windows OS
www.codeplex.com/WiimoteLib

DarwiinRemote - Open source lib for Mac OS
http://sourceforge.net/projects/darwiin-remote

SHARP surface mount 940nm IR emitter
SHARP-GL100MD1MP1

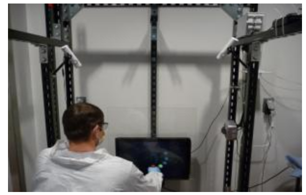
*LabVIEW client code was developed to interact with the open-source Wiimote library (available on request)

Bill of materials

Part	Cost
2 Wiimotes	$80
USB Bluetooth dongle	$7
IR LED	$3
Power supply	$36
2 Camera brackets	$34
Software LabVIEW* Wiimote library	Free
Total	$160*
*(excludes computer cost)	

Methods: Calibration

The photograph shows the WiiMoCap system in operation as a subject performs a reaching task.



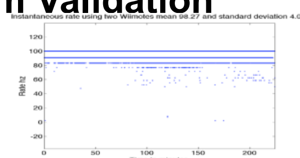
Calibration is the process of converting raw position coordinates reported by a Wiimote into workspace coordinates. Calibration is performed at the beginning of a training session, it is easy to perform and takes less than one minute.

The raw position coordinates (x,y) of the sensed IR marker is transformed into workspace coordinates by multiplying by a calibration matrix. The calibration matrix is obtained by placing the IR marker on predetermined locations in the workspace (indicated by a red dot on the screen). The mapping of raw coordinates of an IR marker to its 2D screen coordinates is obtained through a least-square fit of raw coordinates to the known 2D screen coordinates. A quadratic position term in the least-square model was used to account for weak nonlinearities in the optical sensor.

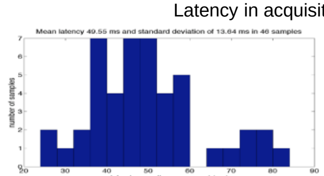
Results: System Validation

Acquisition rate: 98 Hz

The acquisition rate of the WiiMoCap system was measured using a LabVIEW client. A mean refresh rate of 98 Hz (standard deviation 4 Hz) was sustained over a period of 3.7 hrs, verifying the stability of the data acquisition system.



Latency in acquisition: 50 ms



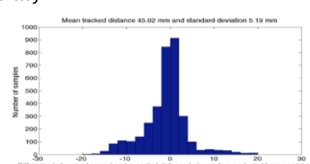
The acquisition delay or latency in a Wiimote includes detection and transmission delays. The mean latency in acquisition of the Wiimote was 49.6 ms (standard deviation 13.6 ms).

The delay in data acquisition was measured using the rising edge of an electrical signal as reference in 46 trials.

Tracking Accuracy: 1 mm

Accuracy of the WiiMoCap system was measured to be within (1 + 5 mm). The distance reported by the acquisition system between two IR markers (46 mm apart) when they were moved in a calibrated workspace, was used as the test for tracking accuracy.

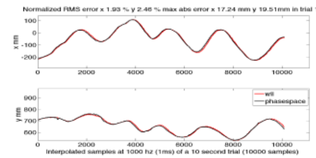
Thirteen calibration points and a quadratic position term in the calibration model was used to track the point sources with a mean reported distance of 45.02 mm (standard deviation 5.19 mm).



Results: System Validation

WiiMoCap vs Phasespace

max nRMS < 3 %, max absolute error < 40 mm



The WiiMoCap system was validated with the data recorded simultaneously from a six camera Impulse system from Phasespace Inc. The Impulse camera system streamed data at 120 Hz. Each camera has a resolution of 3,600 x 3,600 pixels, and a 60 degree field of view.

Normalized RMS and max absolute error from coordinates reported by the Impulse system were used to verify the system performance.

Results: Summary

System Validation	Mean	Standard Deviation
Acquisition Rate tested over 3.7hrs	98.27 Hz	4.02 Hz
Latency in capture 46 trials	49.55 ms	13.64 ms
Accuracy Test : distance between 2 IR markers 46 mm	45.02 mm	5.19 mm
System Validation Pooled across 16 trials	**Normalized RMS error (x,y) %**	**Maximum absolute error (x,y) mm**
Validation with Phasespace Impulse motion capture system	(1.27, 2.67)	(18.47, 39.36)

Conclusion

The WiiMoCap system performance is on par with Phasespace motion capture system, calibration tests demonstrate the system is robust and tracks reliably in a 2D workspace. The WiiMoCap system is a viable alternative to a touchscreen or planar manipulandum, used to track movement in a psychophysics and behavioral neurophysiology laboratory.

We have been using the system successfully since June 2009 to train non-human primates to perform drawing and pointing movements in the laboratory.

References

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