USC University of Southern California

USC Institute for Creative Technologies

USC Viterbi School of Engineering

Ming Hsieh Department of Electrical Engineering

Towards Pervasive Physical Rehabilitation Using Microsoft Kinect

Chien-Yen Chang[1], Belinda Lange[1], Mi Zhang[2], Sebastian Koenig[1],
Phil Requejo[3], Noom Somboon[3], Alexander A. Sawchuk[2], and Albert A. Rizzo[1]
[1]Institute for Creative Technologies, University of Southern California, Playa Vista, CA
[2]Ming Hsieh Department of Electrical Engineering, University of Southern California, Los Angeles, CA
[3]Rancho Los Amigos National Rehabilitation Hospital, Downey, CA

Motivation

- In the US, approximately 265,000 people have spinal cord injuries (SCI). People with such motor deficiencies experience dramatic limitations in performing everyday activities
- Conventional rehabilitation training programs provide limited objective performance measures and typically lack engaging content to motivate individuals during intervention

Challenges

- Most existing VR technologies incorporate Marker-based motion capture capability that inhibits the patient's already limited movement
- They are also relatively expensive and typically housed at large medical facilities, requiring a patient visit and further increasing operational cost
- Existing work has shown the potential of Kinect as a useful VR rehabilitation tool, though the technical performance of Kinect is not well understood

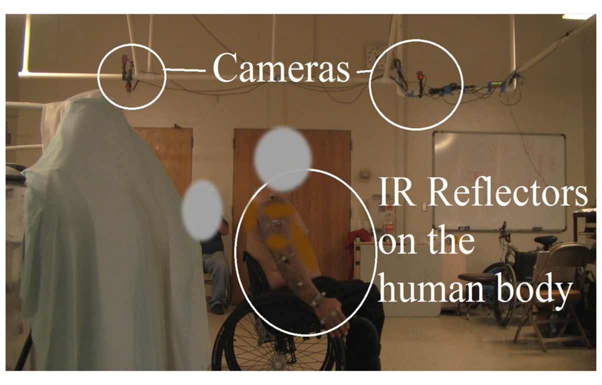
Objective

- To investigate the capability of Microsoft Kinect as a robust tool for Spinal Cord Injury rehabilitation by comparing the outputs of Kinect with the OptiTrack as ground truth to validate whether Kinect can be used as a feasible rehabilitation tool.
- We recorded right hand, elbow and shoulder trajectories of 2 subjects for 6 motor tasks commonly used for rehabilitation of Spinal Cord Injuries. A game was developed which incorporates the 6 tasks.

OptiTrack Optical Motion Capture System and Microsoft Kinect

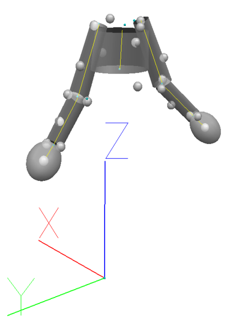
Device	Microsoft Kinect	OptiTrack
Picture		
Description	a "marker-free" motion sensing input device developed as a peripheral device for use with the Xbox 360 gaming console2.	A high performance marker-based optical motion capture system, requires users to wear reflective markers such that their movements can be tracked by an array of cameras.
Model	Xbox 360	OptiTrack V100:R21
Resolution	640 × 480	640 × 480
Frame Rate	30 FPS	100 FPS
Sensing Range	1.2 to 3.5m	20m
Field of View	Horizontal: 57°, Vertical: 43°	360°
Number of Cameras	1	Multiple
Markers	No	Yes
Cost	Low	High
Environment	Clinic, Home	Medical Center
Software for signal access	OpenNI/NITE	—

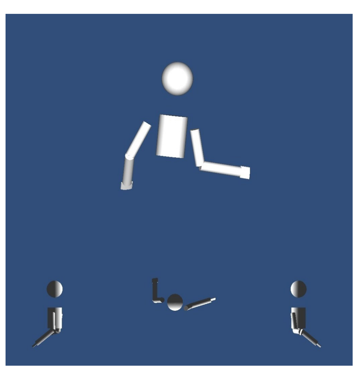
System Setup



The deployment of the OptiTrack cameras


The placement of the reflective markers on the upper body

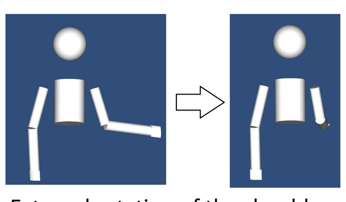

Avatar with markers


Avatar in the game

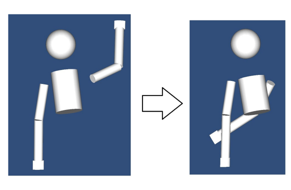
Experimental Setup

- Two participants (one male with SCI and one healthy female) were recruited at Rancho Los Amigos National Rehabilitation Center Rehabilitation Engineering Laboratory
- Six different motor tasks were performed and recorded

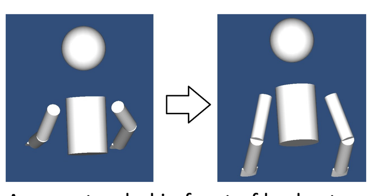
- **External Rotation**


External rotation of the shoulder with elbow at 90 degrees flexion

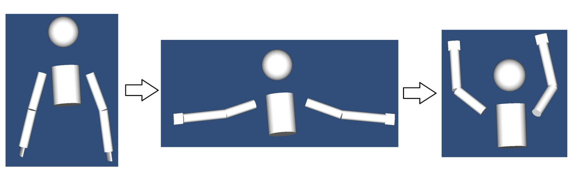
- **Shoulder Adduction (Diagonal Pull Down)**


Shoulder flexion and adduction from arm above head across midline of body towards opposite knee with elbow extended

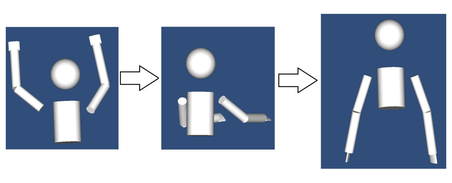
- **Scapular Retraction**


Arms extended in front of body at 45 degrees flexion, elbows extended -flexing elbows to bring hands back towards body

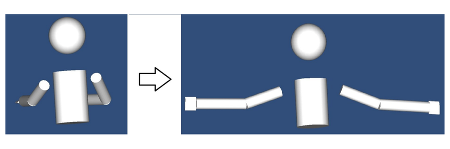
- **Shoulder Abduction**


Shoulder abduction with elbow extended

- **Shoulder Flexion**


Shoulder flexion with elbow extended

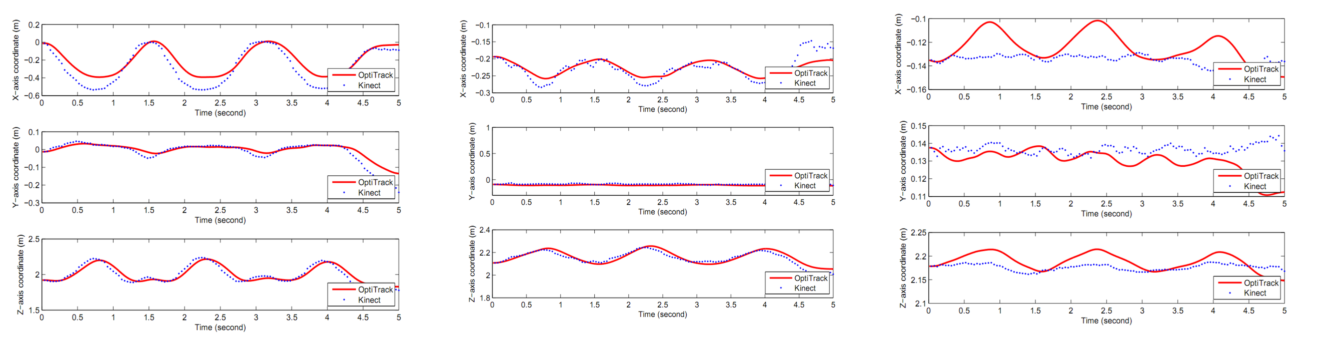
- **Shoulder Extension**


Arm outstretched in front of body at 90 degrees flexion, elbow extended to arm outstretched at side at 90 degrees abduction, elbows extended

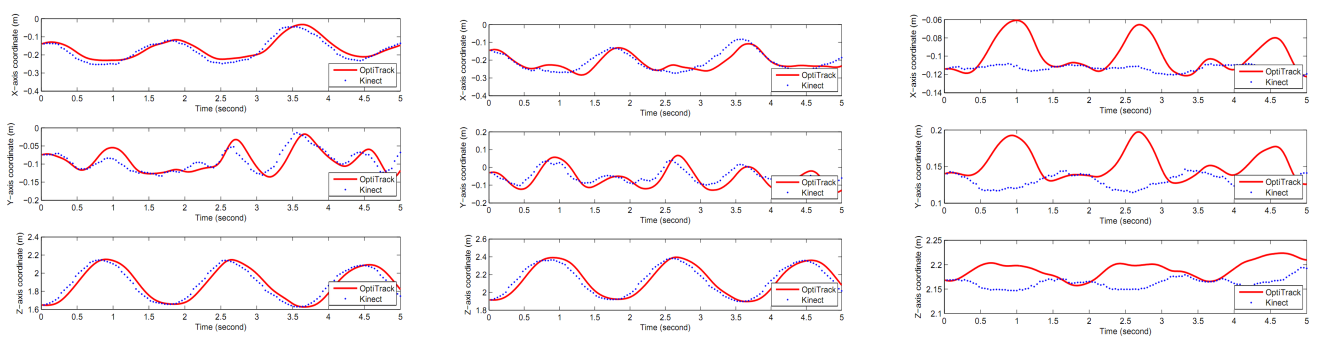
Experimental Result

- **Trajectory comparison**

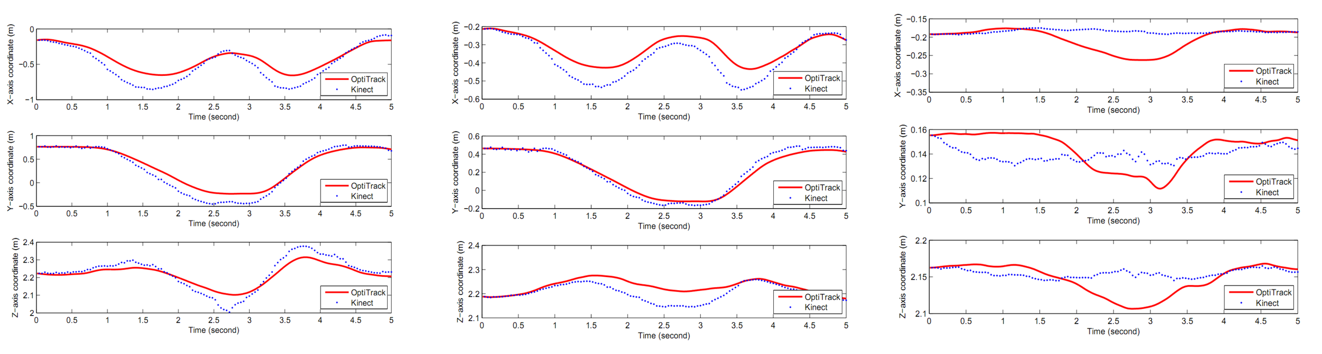
External Rotation


(a) The x, y, and z-axis trajectories of right hand (b) The x, y, and z-axis trajectories of right elbow (c) The x, y, and z-axis trajectories of right shoulder

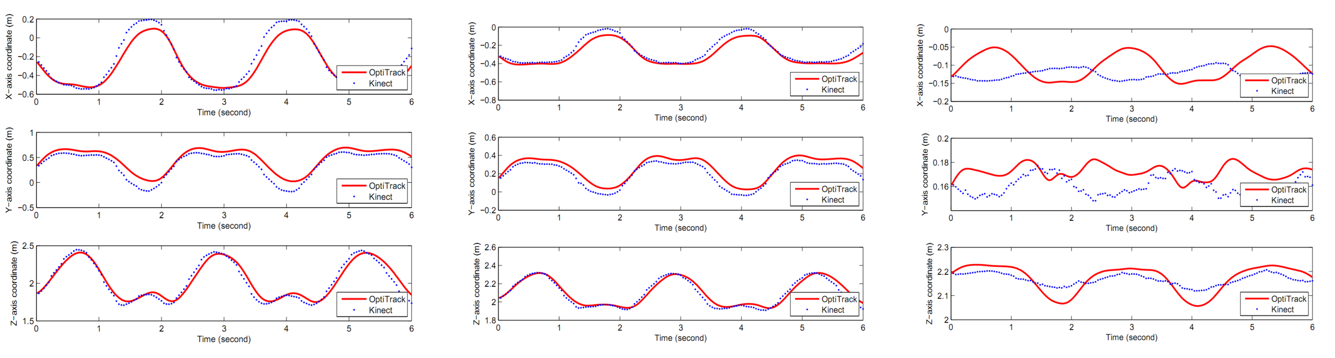
Scapular Retraction


(a) The x, y, and z-axis trajectories of right hand (b) The x, y, and z-axis trajectories of right elbow (c) The x, y, and z-axis trajectories of right shoulder

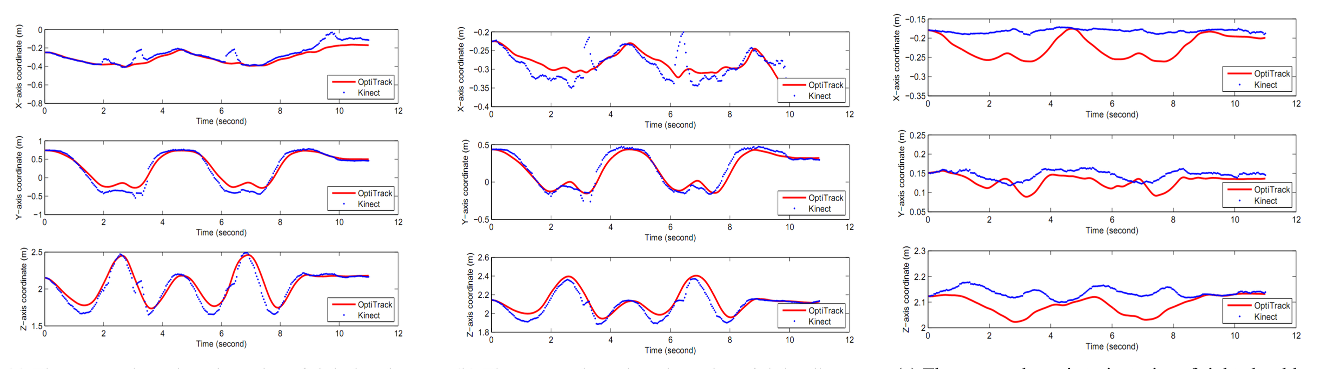
Shoulder Abduction


(a) The x, y, and z-axis trajectories of right hand (b) The x, y, and z-axis trajectories of right elbow (c) The x, y, and z-axis trajectories of right shoulder

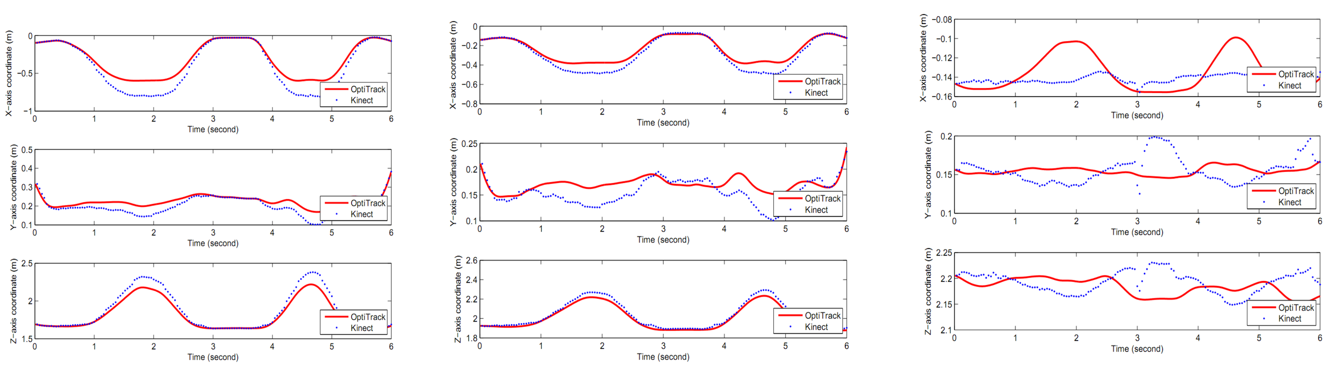
Shoulder Abduction


(a) The x, y, and z-axis trajectories of right hand (b) The x, y, and z-axis trajectories of right elbow (c) The x, y, and z-axis trajectories of right shoulder

Shoulder Flexion


(a) The x, y, and z-axis trajectories of right hand (b) The x, y, and z-axis trajectories of right elbow (c) The x, y, and z-axis trajectories of right shoulder

Shoulder Extension


(a) The x, y, and z-axis trajectories of right hand (b) The x, y, and z-axis trajectories of right elbow (c) The x, y, and z-axis trajectories of right shoulder

- **Observation**: For all six motor tasks, the tracking of hand and elbow are closely matched in each axis between Kinect (blue dotted line) and OptiTrack (red curve). However, the six movements at the shoulder are not tracked well by the Kinect.
- **Timing Performance Comparison**: We use cross-correlation as the evaluation metric. OptiTrack is 50 milliseconds faster than Kinect. This difference is negligible for our rehabilitation application.

Game Design

- **Game development engine:** Unity3 Pro
- **Motor Task in this game:** External Rotation
- **Game Flow**

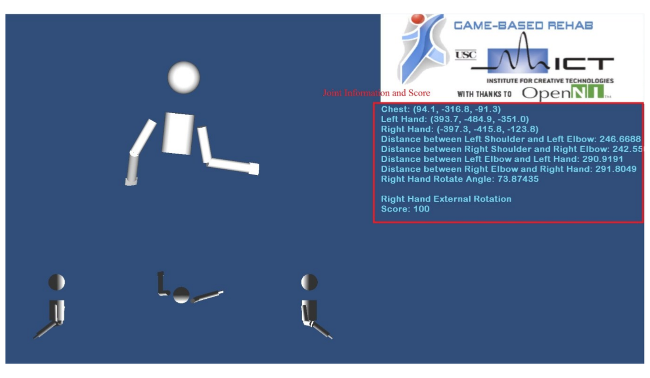
1. Calibration: Before the game starts, the clinician can define the amount and the accuracy of the motor task by defining the coordinates of the starting and end point of the motor task. As a necessary calibration step, the patient is asked to rotate his/her upper limb as much as possible such that the maximum rotation angle is recorded.
2. Game play: The below figure shows a sequence of game screenshots.

(a) At the beginning of the game, the player is instructed to grab the capsule using the right hand

(b) The green color indicates the player's movement is correct

(c) The player successfully finishes the movement

A sequence of screenshots of our rehabilitation game



The interface to display the joints information of the player

Game Validation

- Each participant performed the motor task "External Rotation" 10 times, 5 trials with correct movements and 5 trials with incorrect movements.
- Result: Our game successfully identified all the incorrect movements by displaying the path in red color.

Conclusion and Future Work

- This initial analysis and comparison of the motion tracking between the low-cost Microsoft Kinect and a high-cost multi-camera lab-based system OptiTrack demonstrates the use of the Microsoft Kinect as a promising VR neurological rehabilitation tool for use in the clinic and home environment.
- Future studies should address the comparison of more movement tasks involved in the rehabilitation interventions with a larger sample of participants with neurological injury.

Acknowledgement

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For more information, please contact Chien-Yen Chang via kchang@ict.usc.edu