# CPS: Home-based Rehabilitation system for knee deficient patients

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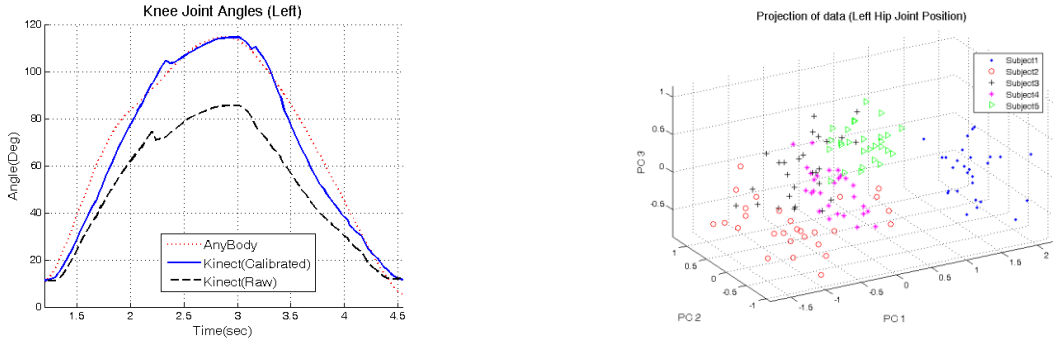
## Background

Our motivation is to develop home-based quantitative rehabilitation methods consists of low-cost measuring device, smart knee brace/exoskeleton and PC-based analysis/monitoring system. Clinic-based rehabilitation consists of expensive motion/force capture hardware/software which is not compatible with home-based system. Effective function of the knee brace/exoskeleton depends both on the designs as well as correct fitting. Unfortunately most of knee brace/exoskeleton design and fitting depend on designer/physiologist's intuition and experience. Hence, we examined quantitative methods to design exoskeleton and evaluated low-cost motion capture sensor, Kinect.

## Brief of Research

We perform comparative analysis of motion data from two alternate human motion-capture systems (Vicon vs Kinect) processed using AnyBody Modeling System and Visual-3D. Direct application of the Kinect system to clinical or research work tends to be limited. However, suitable post processing (kinematic calibration and Kalman filtering) offers potential for applicability for clinically relevant use as shown in Fig. 1-(a).



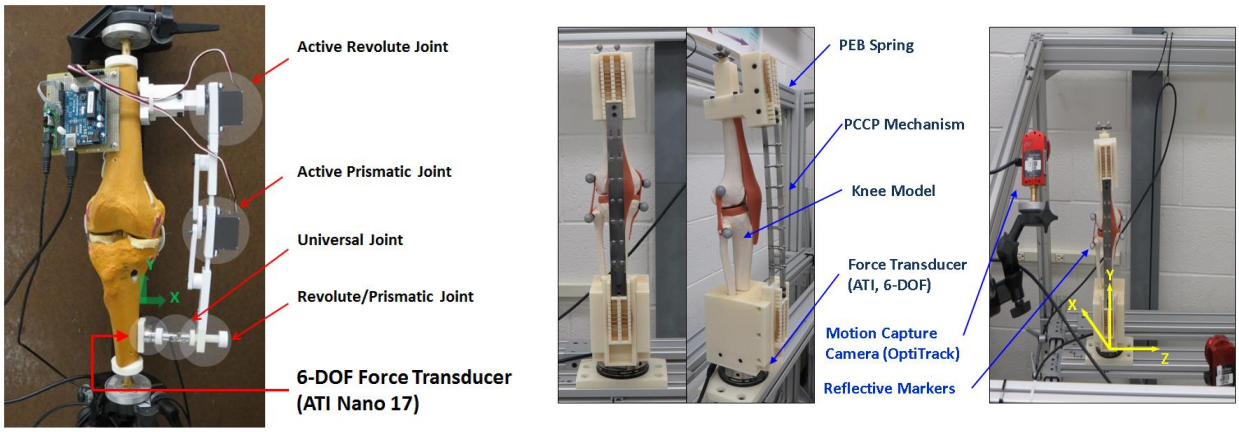

(a) (b)

Fig. 1. (a) Joint angle plots captured by Kinect system/AMS and a kinematically-calibrated Kinect data and (b) Projected left hip joint trajectory of all trials

We seek the capabilities of Kinect and appropriate statistical data-processing to aid individualized-assessment. Data for multiple trials of squatting motions were captured by Kinect and Principal Component Analysis approaches facilitated both dimension-reduction and filtering while the K-Nearest Neighbors method was adapted for subject classification (95.6% classification accuracy, Fig. 1-(b)).

A systematic and quantitative methodology to evaluate various alternate exoskeleton designs using twist- and wrench- based modeling and analysis was proposed. This process is applied in

the context of a case-study for developing optimal configuration and fixation of a knee brace/exoskeleton. An optimized knee brace is then prototyped using 3D printing and instrumented with 6–DOF force-torque transducer as shown in Fig. 2 – (a).




(a) (b)

Fig. 2. (a) Scaled active knee krace for optimal configuration and (b) full scaled PCCP/PEB prototype

Compliant mechanisms offer a class of articulated multibody systems that allow relatively stiff but lightweight solutions for exoskeleton/braces. We introduced Parallel Coupled Compliant plate (PCCP) mechanism and Pennate Elastic Band (PEB) spring architecture and evaluate it. PCCP/PEB system provides both flexibility and extreme stiffness to user with respect to posture/angle of knee joint without mediation of active devices and sensors shown in Fig. 2 – (b). All publication regarding for those work is following:

1. ***Seungkook Jun***, X. Zhou, D. Ramsey, V. Krovi, Automation for Individualization of Kinect-based Quantitative Progressive Exercise Regimen, IEEE International Conference on Automation Science and Engineering, Madison WI, August 17-21 2013.
2. ***Seungkook Jun***, X. Zhou, D. Ramsey, V. Krovi, Kinetostatic Design-Refinement of Articulated Knee Braces, ASME 2013 International Design Engineering Technical Conferences and Computers in Engineering Conference, Portland Oregon, August 4-7 2013.
3. ***Seungkook Jun***, X. Zhou, D. Ramsey, V. Krovi, A Comparative Study of Human Motion Capture and Analysis Tools, Digital Human Modeling Symposium, Ann Arbor MI, June 11-13 2013.
4. ***Seungkook Jun***, X. Zhou, D. Ramsey, V. Krovi, Knee Exoskeleton Design with Parallel Coupled Compliant Plate (PCCP) Mechanism and Pennate Elastic Band (PEB) Spring, International Conference on Intelligent Robots and Systems, Chicago, IL September 14-18 2014 (submitted)
5. ***Seungkook Jun***, X. Zhou, D. Ramsey, V. Krovi, Quantitative Methodology for Knee Exoskeleton Design, International Design Engineering Technical Conferences and Computers in Engineering Conference, Buffalo, NY, August 17-20 2014 (Submitted)

## Discussion

In our recent study, we evaluated the accuracy and capability of Kinect senor (low-cost human motion capturing solution) and provided calibration/filtering method to enhance the performance of Kinect. In addition to measuring, a quantitative and systematic design process for knee exoskeleton was introduced and a prototype of compliant but selectively stiff and lightweight knee exoskeleton design was developed and evaluated.