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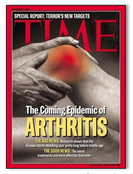
Mechanical and Aerospace Engineering (SEAS), Exercise & Nutrition Sciences (SPHHP)

Cyber Physical System: Home-based Rehabilitation System for Knee Deficient Patients

Motivation

- Osteo-Arthritis (OA) impacts 20 million people (7.35%) and 80,000 Anterior Cruciate Ligament (ACL) injuries occur in the USA per year
- By 2030, nearly 67 million diagnosed with OA



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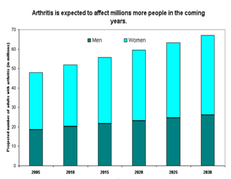
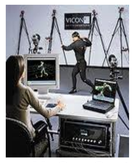


- Clinical gait analysis currently involves high-fidelity and expensive motion- and force - capture by skilled practitioners


Vicon MoCap System


Kinect Sensor & Wii Balance Board

- Some concepts for interactive home-based diagnosis for knee deficit patients are under development

- We evaluate potential of commercial-off-the-shelf (COTS) devices – Kinect, Wii balance board – as a viable assessment tool for home-based system.

Acknowledgement

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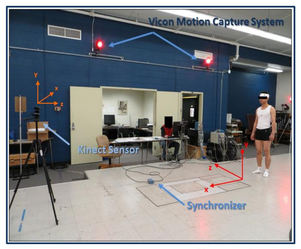
Publications

- S. Jun, X. Zhou, D. Ramsey, V. Krovi, Knee Exoskeleton Design with Parallel Coupled Compliant Plate (PCCP) Mechanism and Pennate Elastic Band (PEB) Spring, IEEE/RSJ International Conference on Intelligent Robots and Systems, Chicago, IL, September 14-18, 2014 (on processing).
- S. Jun, X. Zhou, D. Ramsey, V. Krovi, Quantitative Methodology for Knee Exoskeleton Design, ASME 2014 International Design Engineering Technical Conferences and Computers in Engineering Conference, Buffalo, NY, August 17-20 2014 (on processing).
- S.K. Jun, S. Kumar, X. Zhou, D. Ramsey and 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.
- S.K. Jun, X. Zhou, D. Ramsey and 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.
- S.K. Jun, X. Zhou, D. Ramsey and V. Krovi, A Comparative Study of Human Motion Capture and Analysis Tools, Digital Human Modeling Symposium, Ann Arbor MI, June 11-13 2013.

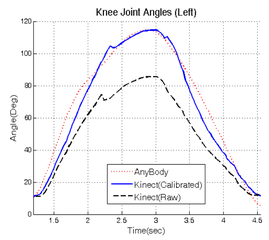
Measuring – Motion Capturing and Force Measuring

Motion capture from Vicon and Kinect system

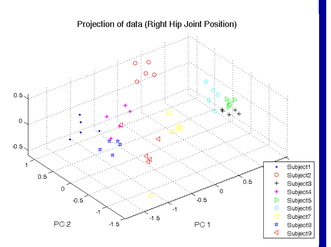
Raw Kinect measurements can be improved to a satisfactory level by kinematic calibration and Kalman filtering (in selected cases)



MoCap System Configuration



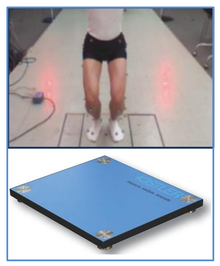
Data from kinematic calibration (error - 2~9 degree)

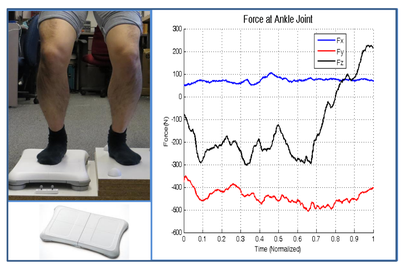


Projected Right Hip Joint Trajectory (Human Identification, squatting)

Force Measure from Force Plate and Wii Balance Board

Will balance board has a limit (3-DOF) but enough for quasi-static measurement


Force Plate (Kistler)

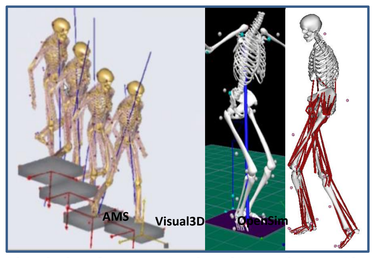


Wii Balance Board Setup and Force at Ankle Joint

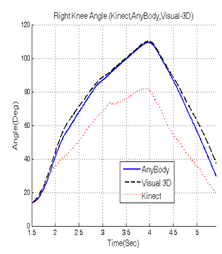
Analysis – Computational Musculoskeletal Analysis

Dynamic Analysis

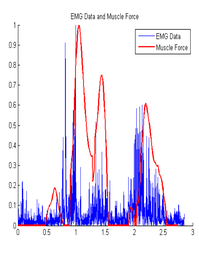
Anybody Motion System (AMS), OpenSim, or Visual3D offer computational musculoskeletal analysis framework for analyzing human musculoskeletal interactions with the physical environment (forward/inverse dynamic analysis)



Simulation from AMS, Visual3D and OpenSim



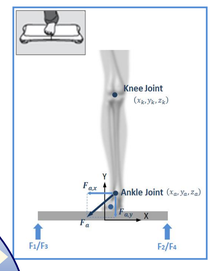
Joint Angle

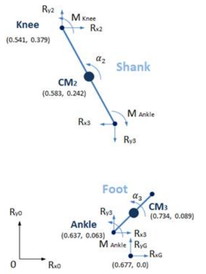


Muscle Force and EMG

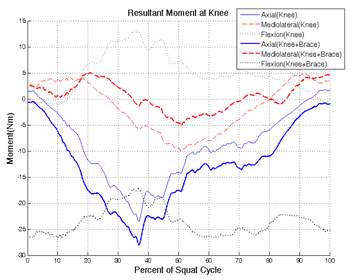
Simplified Lower Limb Model (Newton – Euler Method)

Simplified but clinically feasible model for real-time analysis





FBD

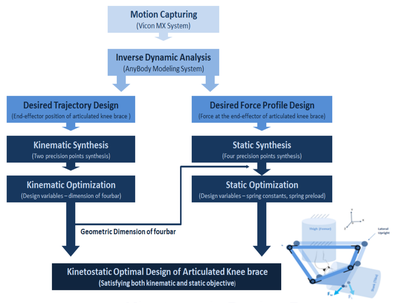


Moment at Knee Joint

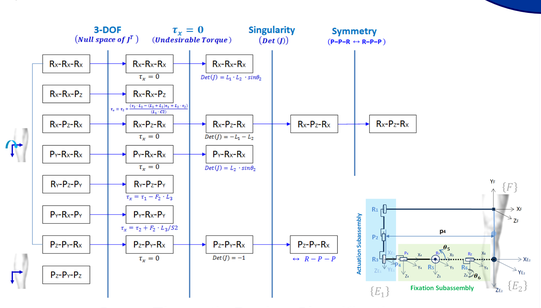
Design – Knee Exoskeleton

Kinetostatic Optimization & Screw Theoretic Analysis

Quantitative and systematic design process for knee exoskeleton



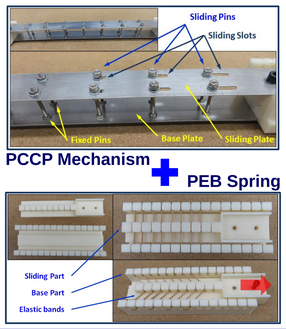
Kinetostatic Design Process



Screw Theoretic Design Classification

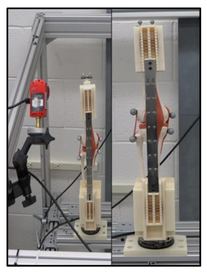
Compliant/Selectively Stiff/Lightweight Knee Exoskeleton

Parallel Coupled Compliant Plate (PCCP) Mechanism and Pennate Elastic Band (PEB) Spring (Extreme stiffness at excessive joint angle, assistive load at normal motion range, light weight – 143g, 0.32lbs)



PCCP Mechanism + PEB Spring =


PCCP/PEB Knee Exoskeleton


Performance Test

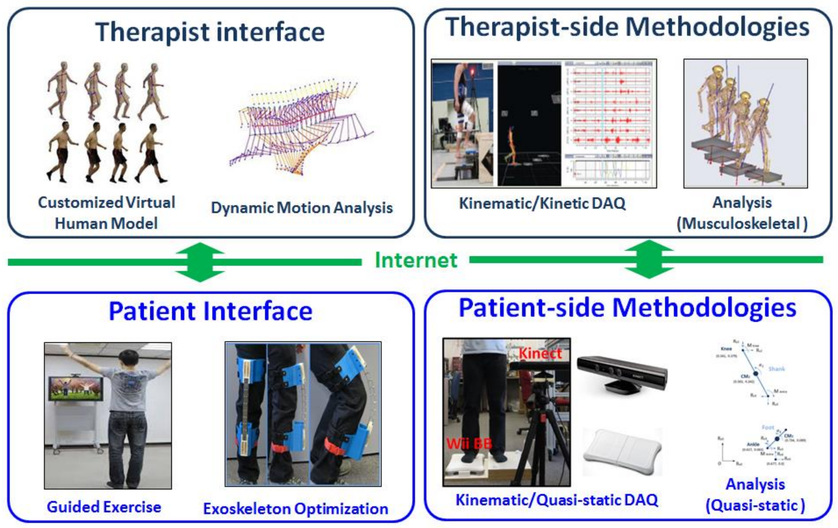
Integrated Monitoring System

Remotely Adjustable Smart Knee Exoskeleton

Triple convergence of miniaturization of sensing/actuation coupled with advances in computing and communication creates a class of smart, lightweight, wearable and yet adaptive, versatile and reprogrammable rehabilitative devices

Cyber Physical Framework

Home-based rehabilitation programs are realized by launching of smart embedded products such as Kinect and Wii Balance System



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