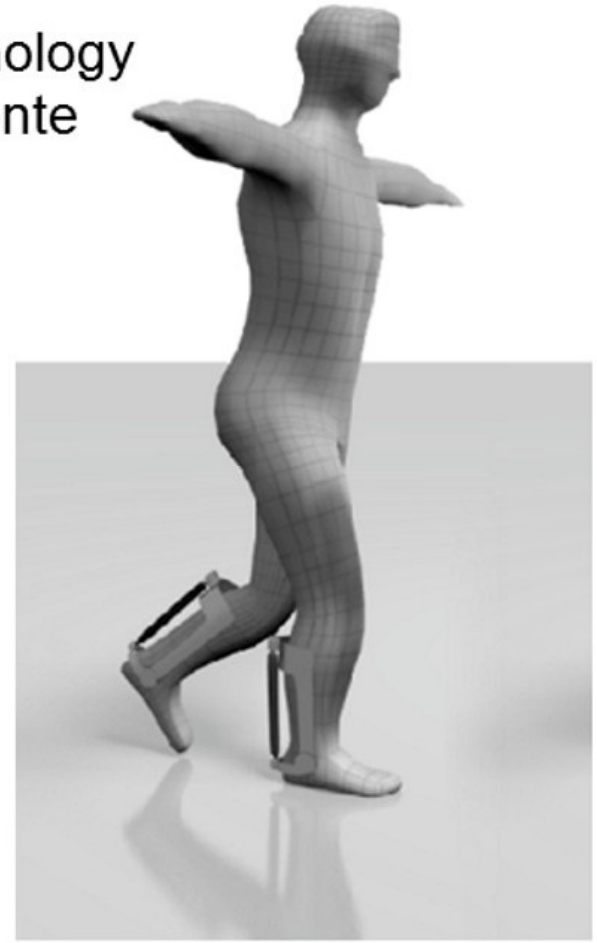
Optimization of Human Walking for Exoskeletal Support

W. van Dijk: Delft University of Technology
H. van der Kooij: University of Twente

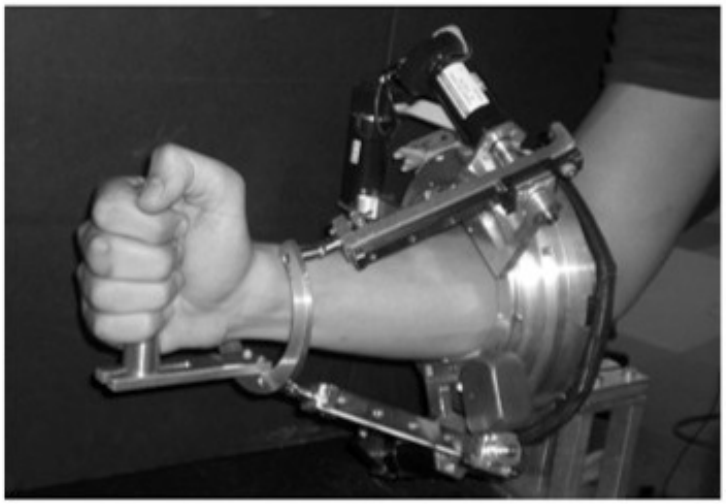


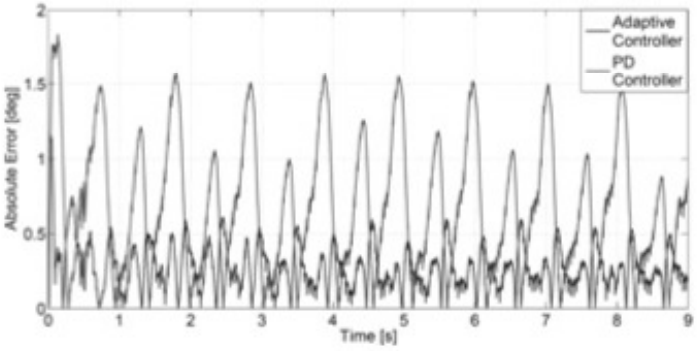
- The Geyer Muscle-Reflex model is used to simulate walking with an ankle exoskeleton.
- The model captures the human adaptation to the exoskeleton
- Muscle activations and metabolism changes are predicted with the model

Poster A1

Adaptive Control of a Serial-in-Parallel Robotic Rehabilitation Device

Ali Utku Pehlivan, Fabrizio Sergi, and Marcia K. O'Malley





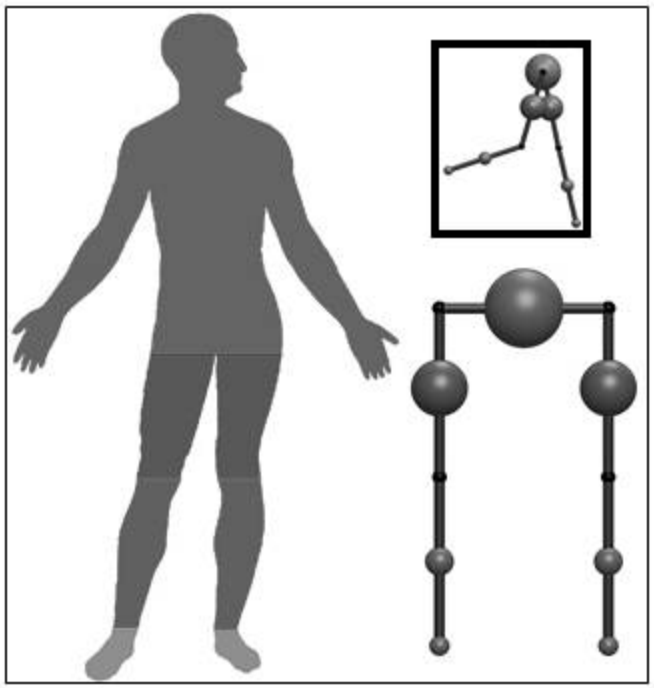
- The domain of the workspace of the serial-in parallel mechanism in which local stability can be shown is defined
- A passivity based adaptive controller which aims to estimate the ability of the patient is implemented
- The suitability of the adaptive controller to rehabilitation use is compared with a position-derivative controller

Poster A2

Comparison of the Passive Dynamics of Walking on Ground, Tied-belt and Split-belt Treadmills, and via the Gait Enhancing Mobile Shoe (GEMS)

Ismet Handzic and Kyle. B. Reed
University of South Florida

- Passive dynamics of walking affects the gait patterns, but are difficult to study directly in humans.
- Passive Dynamic Walkers (PDW) can allow for the comparison of the passive dynamics separate from the cognitive influences of gait.
- Normal and perturbed PDW and human gaits were compared showing similar trends when the dynamics were altered.



Poster A3

The Biomechanics and Energetics of Human Running Using an Elastic Knee Exoskeleton

Grant Elliott (MIT), Gregory S. Sawicki (NCSU)
Andrew Marecki (MIT), Hugh Herr (MIT)

- A clutch-spring exoskeleton has been developed to externally supplement the elastic behavior of the biological knee in running
- Pilot data show no significant evidence of change in biological or total knee stiffness while using the device but may suggest differing responses between recreational and long-distance runners
- The device has potential augmentative and rehabilitative applications

Poster A4

A Soft Robotic Exomusculature Glove with Integrated sEMG Sensing for Hand Rehabilitation

Michael A Delph, Sarah A Fischer, Phillip W Gauthier, Carlos H. Martinez Luna, Edward A. Clancy, Gregory S. Fischer

Worcester Polytechnic Institute, Worcester, MA USA
Liberating Technologies, Inc., Holliston, MA, USA

- Rehab Robotic platform for stroke hand rehabilitation
- Use Surface EMG to control system for active assistance, active resistance
- Each finger is independently controlled
- Mobile platform for repetitive motion therapy

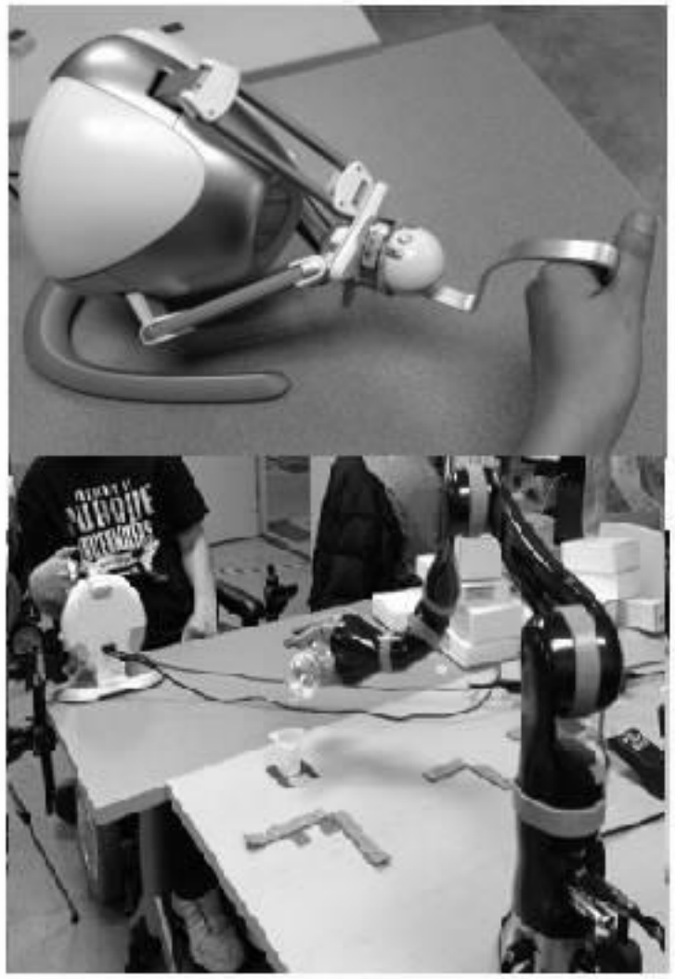
AIM
WPI Automation and Interventional Medicine Laboratory

Poster A5

3D Joystick for Robotic Arm Control by Individuals with High Level Spinal Cord Injuries

H. Jiang, J.P. Wachs, M. Pendergast, B.S. Duerstock: Purdue University

- A 3D Joystick has been developed to enable quadriplegics due to spinal cord injuries efficiently operate a robotic arm
- Compared to two different manual input modalities: a keyboard control and a traditional joystick control
- Targeting and pouring experimental results illustrated the advantages for 3D joystick in robotic control

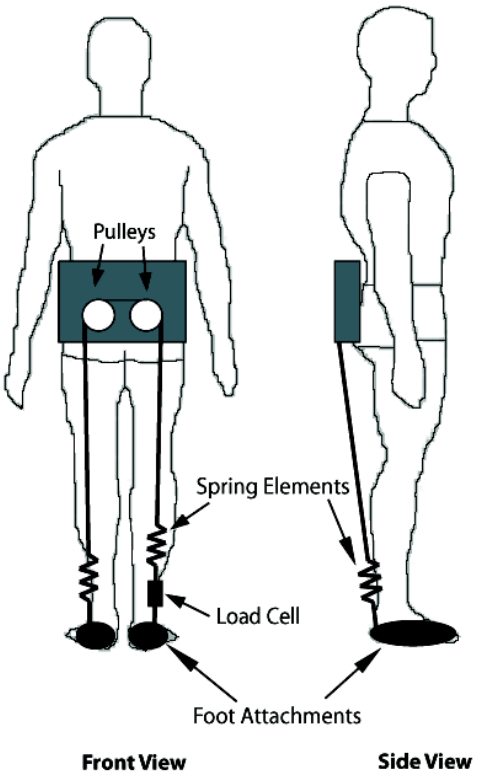


Poster A6

Investigation of a passive inter-limb device on step-to-step transition of human walking

J Zhang: Queen's University, Canada
Q Li: Queen's University, Canada

- A passive inter-limb device was developed to transfer energy between legs during step-to-step transition.
- Metabolic and ground reaction forces were measured during 10 minutes of walking with the device active and passive
- Preliminary results show a decrease in mechanical work performed by the leading and trailing leg but an increase in the subjects rate of metabolic expenditure when using the device.

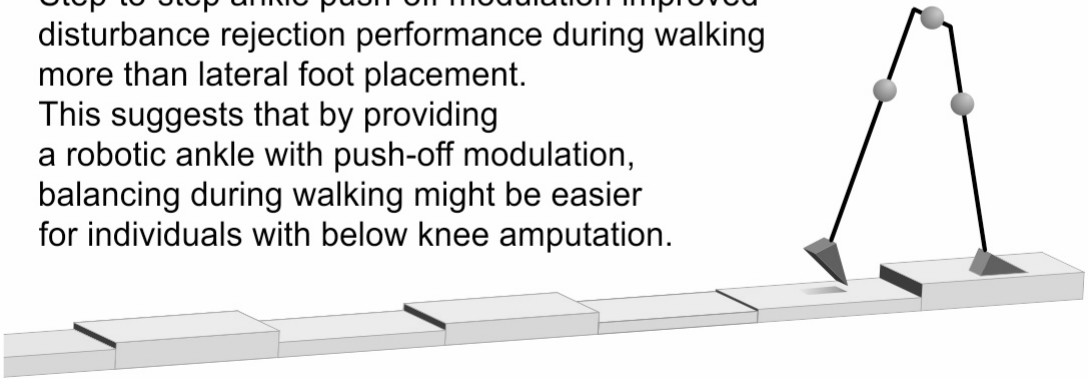


Poster A7

Stabilization of a Three-Dimensional Limit Cycle Walking Model through Step-to-Step Ankle Control

M Kim and S H Collins: Carnegie Mellon University (CMU), USA

- A three dimensional model of human gait was developed with ankle and hip actuation.
- Step-to-step controllers were designed which modulate actuation parameters at each step using LQR.
- Step-to-step ankle push-off modulation improved disturbance rejection performance during walking more than lateral foot placement.
  This suggests that by providing a robotic ankle with push-off modulation, balancing during walking might be easier for individuals with below knee amputation.



Poster A8

Human Motion Intention based Scaled Teleoperation for Orientation Assistance in Preshaping for Grasping

Karan H. Khokar, Redwan Alqasemi, Sudeep Sarkar and Rajiv V. Dubey:
University of South Florida, USA

- Users are assisted to orient remote gripper to desired orientations for grasping by scaling their components of motion that lead to the desired configuration
- The desired configuration for grasping is determined by a Hidden Markov Model trained on user motion data
- Users were able to preshape quicker, faster and with much ease compared to unassisted mode.

Poster A9

Fuel Efficiency of a Portable Powered Ankle-Foot Orthosis

MK Boes, M Islam, YD Li, ET Hsiao-Wecksler
University of Illinois at Urbana-Champaign (UIUC)

- The PPAFO gives plantarflexion and dorsiflexion assistance during gait
- The timing and direction of assistance is determined based on the control mode
- Two control modes (state estimation and direct event) were compared for fuel consumption and net work output
- A pneumatic recycling scheme was introduced for fuel savings
- State estimation with recycling allowed for the most net work output with the least fuel use due to the best-timed assistance

Poster A10

Design and Control of a Two-Wheeled Robotic Walker for Balance Enhancement

A. R. da Silva Jr., F. Sup: University of Massachusetts Amherst

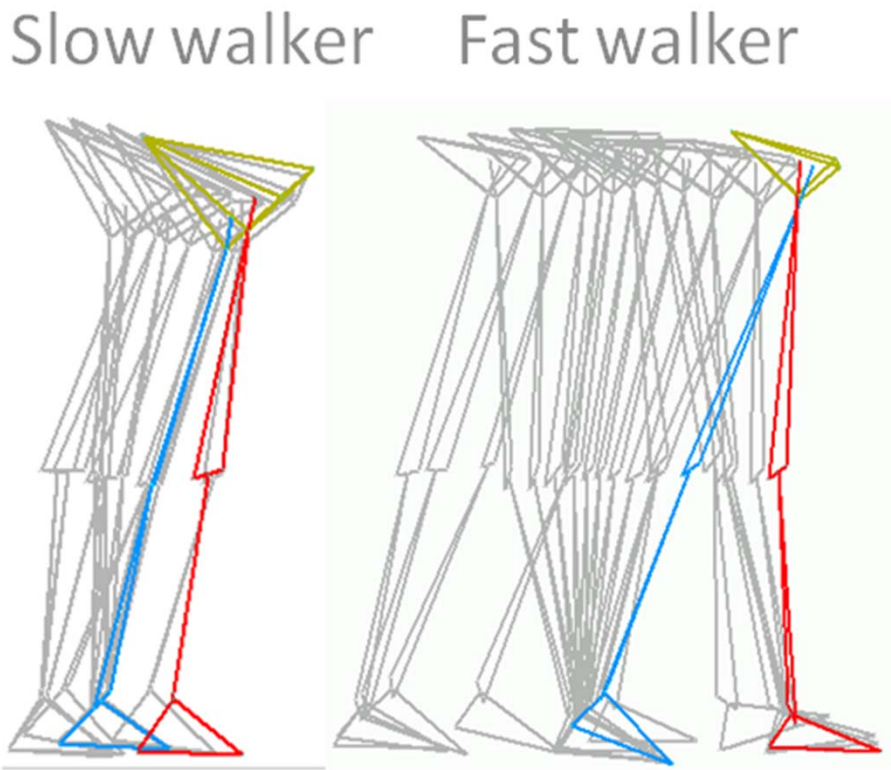
- The conceptual model of a two-wheeled robotic walker has been developed to assist mobility-impaired users with physical functionalities
- A mathematical representation of system dynamics with motor dynamics in two-wheeled mode is developed
- Simulated results demonstrate the effectiveness of two robustly tuned controllers in rejecting external disturbance

Poster A11

Differentiating Ability in Users of the ReWalk™ Powered Exoskeleton (An Analysis of Walking Kinematics)

M. Talaty, A. Esquenazi : Gait & Motion Analysis Laboratory, MossRehab (Albert Einstein Healthcare Network), Elkins Park, PA, USA
Jorge E. Briceño : Universidad Simon Bolivar, Caracas, Venezuela

- ReWalk™ enables paraplegics (thoracic level motor complete) to walk again
- Users were able to walk with widely varying velocities – ranging from 0.05m/s to nearly 0.5m/s – despite identical training
- Injury level did not predict success
- Subtleties in walking technique may allow for improvement and reduction in energy demands in slower walkers

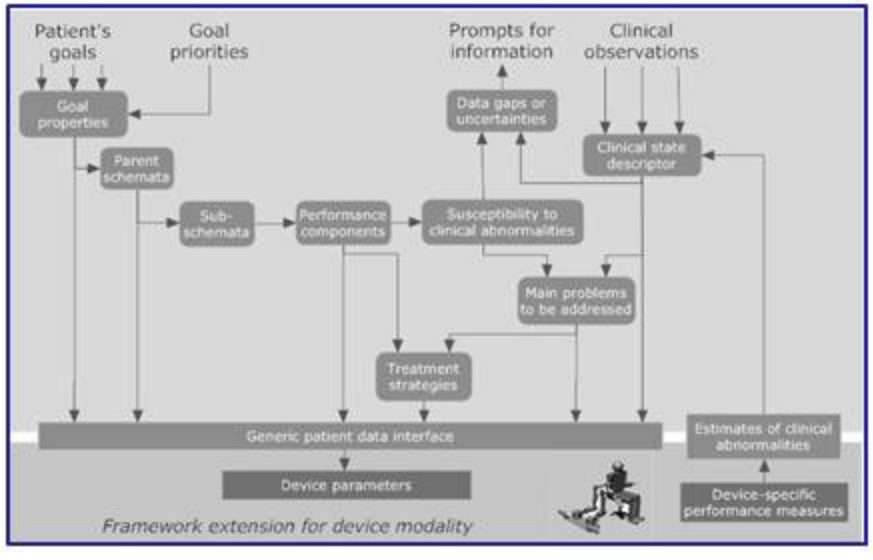


Poster A12

A framework to aid adoption of automated rehabilitation devices into clinical practice

J.A. Cozens, T. Jackson, K. Henderson, S. Brough: NHS Grampian, UK
B. Bhakta and S.G. Makower: Leeds University, UK
F. van Wijck: Glasgow Caledonian University, UK
C. Smith, Salford University, UK

- An informatic framework, "SILCK", has been defined for developing software to control automated rehabilitation devices.
- SILCK bridges the gap between clinical practice and internal device operation, by interpreting patient data to inform the setting of device parameters.

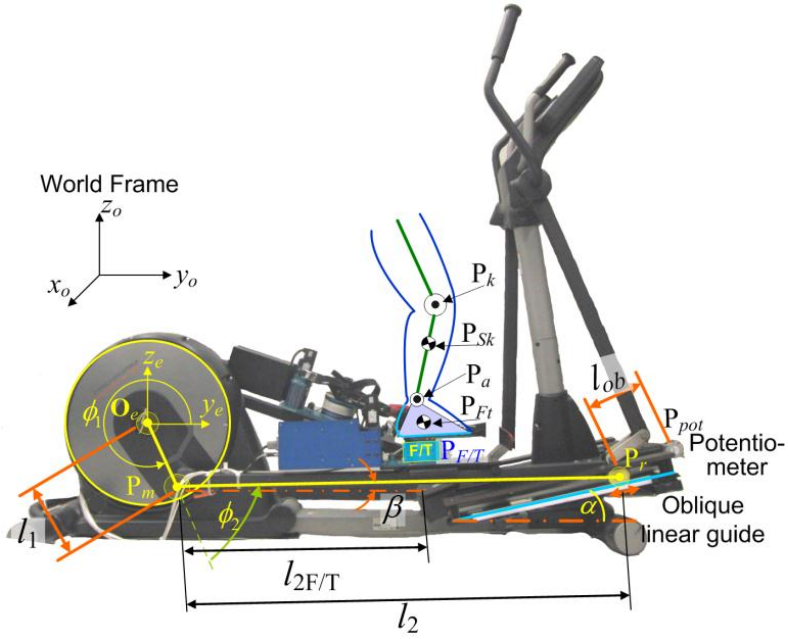


Poster A13

Development of an Elliptical Trainer with Real-Time Knee Adduction Moment Feedback

SH Kang, SJ Lee, Y Ren, LQ Zhang: Rehabilitation Institute of Chicago
Northwestern University (USA)

- The external knee adduction moment (EKAM) is highly associated with knee osteoarthritis (OA).
- A practical *real-time* EKAM estimation method utilizing a simple 6-DOF goniometer was developed to reduce the damaging EKAM during training.
- The proposed method was well-agreed with traditional off-line methods: ICC(2,1)=0.9580.

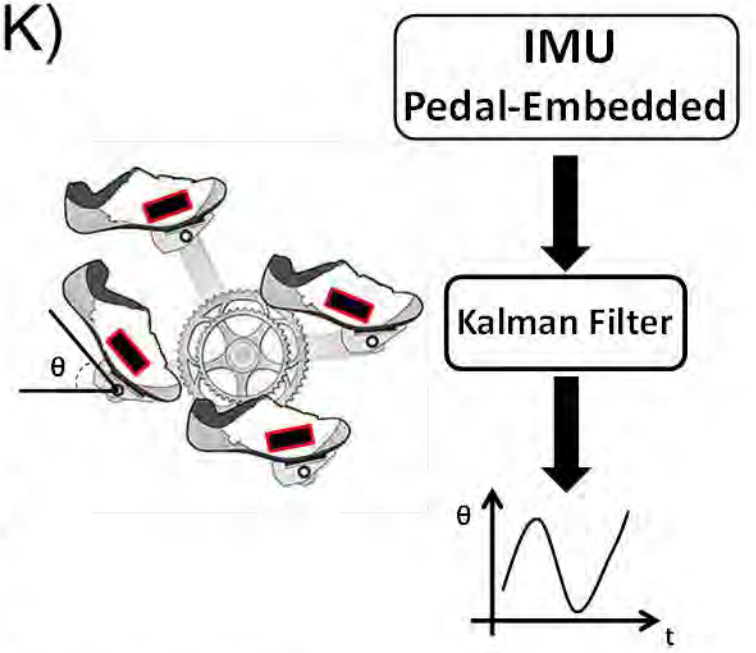


Poster A14

VRACK: Measuring Pedal Kinematics During Stationary Bike Cycling

Amir B. Farjadian[1], Qingchao Kong[1], Venkata K. Gade[2], Judith E. Deutsch[2] and Constantinos Mavroidis[1]
[1] Biomedical Mechatronics Laboratory, Department of Mechanical and Industrial Engineering
[2] RIVERS Laboratory, Department of Rehabilitation and Movement Sciences,

- Virtual reality augmented cycling kit (VRACK) has been developed to measure biomechanical and physiological data.
- Pedal kinematics was measured using IMUs and Kalman filtering.
- Novel encoder-based benchmarking setup was developed.
- Relatively accurate experimental results are presented.

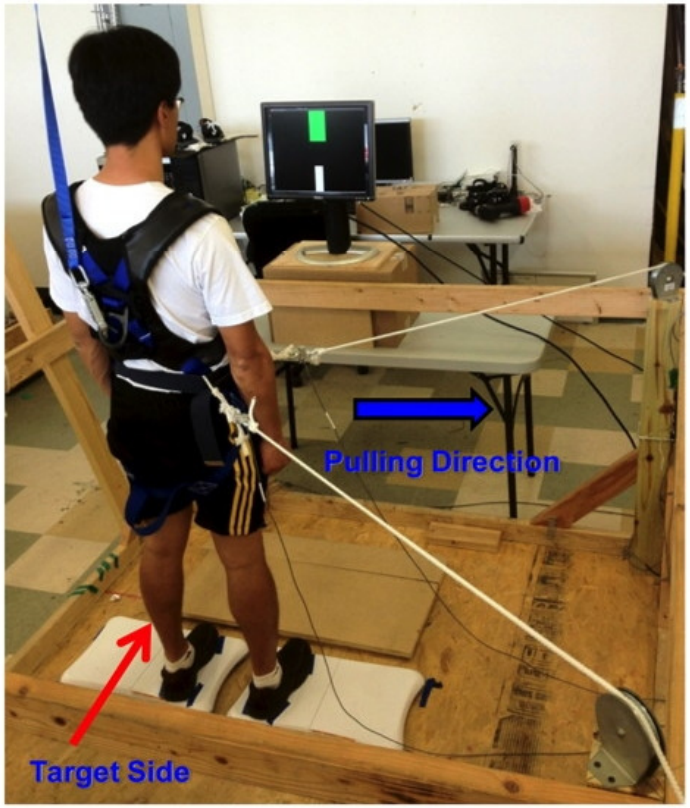


Poster A15

Robot-Assisted Balance Training for Gait Modification

Seok Hun Kim, PT, PhD, School of Physical Therapy & Rehabilitation Sciences
Kyle B. Reed, PhD, Department of Mechanical Engineering
University of South Florida

- We examine if a novel robot-assisted balance training (RABT) program could change human gait patterns.
- An external perturbation was applied to the lower trunk to alter weight distribution patterns during training (shown in figure).
- RABT with stepping movements demonstrated a greater change in gait patterns compared to RABT with standing movements.

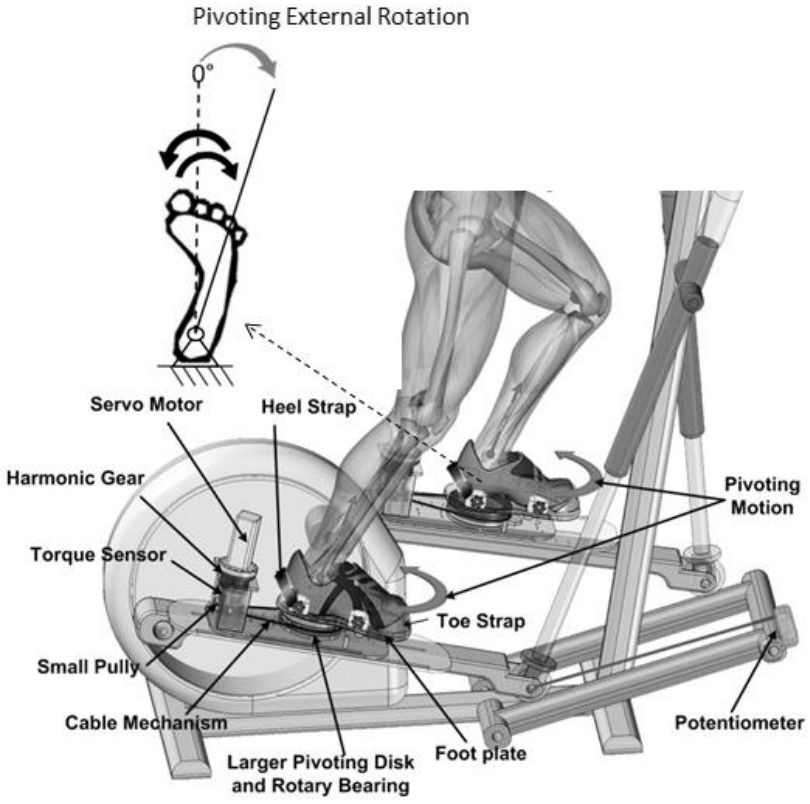


Poster A16

A Pivoting Elliptical Training System for Prevention and Rehabilitation of Musculoskeletal Injuries

Y Ren, SJ Lee, HS Park, LQ Zhang: Rehabilitation Institute of Chicago
Northwestern University (USA)

- A Pivoting Elliptical Training System (PETS) for preventing and rehabilitating musculoskeletal injuries
- Capabilities of allowing axial plane pivoting motion during sagittal stepping with biofeedback and various training modes
- Various Training/Evaluation Modes of Lower Extremity Stability with Different Pivoting Control Algorithms



Poster A17

Adaptation of Task Difficulty in Rehabilitation Exercises Based on the User's Motor Performance and Physiological Responses

Navid Shirzad, H. F. Machiel Van der Loos
UBC Mechanical Engineering

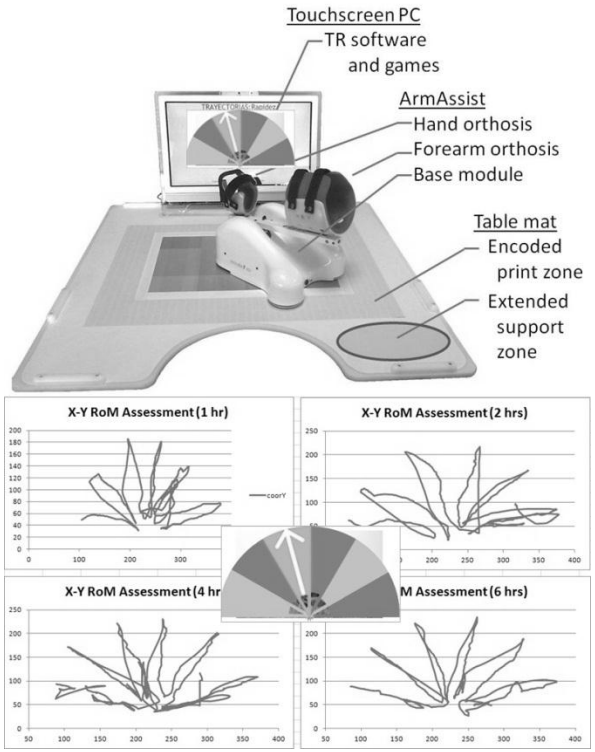
- Exploring use of machine learning algorithms to predict users' desirable difficulty to offer a more engaging therapy regimen
- Used a robot-assisted reaching task with different levels of error amplification to elicit different performance levels and physiological signal responses
- Results showed higher prediction accuracy when using the user's performance as an input compared to the user's physiological signals

Poster A18

Improving the match between ability and challenge: toward a framework for automatic level adaptation in game-based assessment and training

JC Perry, S Balasubramanian, C Rodriguez-de-Pablo, T Keller
TECNALIA Research & Innovation

- A method and set of games for home-based assessment of motor impairment and game level adaptation structure
- Measurement of arm reach and vertical lifting force during developed assessment tasks
- Pilot result of motion range and control progression for single stroke patient illustrate the potential for mobility assessment with the ArmAssist system



Poster A19

A Finger Exoskeleton for Rehabilitation and Brain Image Study

Zhenjin Tang, Shigeki Sugano and Hiroyasu Iwata
Department of Modern Mechanical Engineering
Waseda University, Tokyo 169-8555, Japan

This paper introduces the design, fabrication and evaluation of the second generation prototype of a magnetic resonance compatible finger rehabilitation robot. The mechanical design of the current generation has overcome several disadvantages of the previous version.

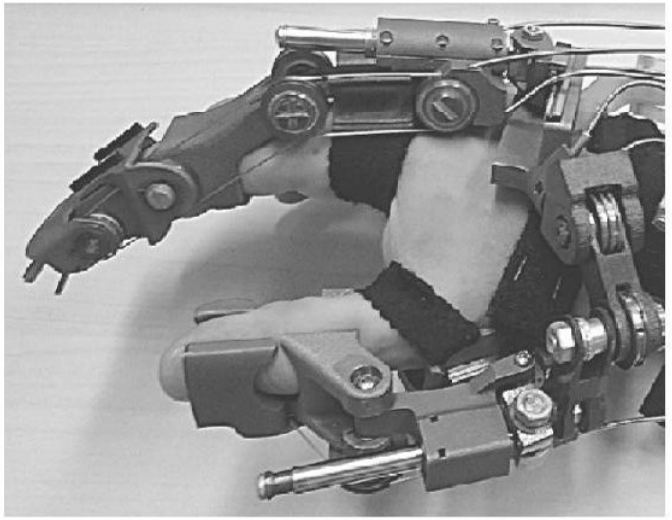
In addition, in order to study the brain activation under different training strategies, three control modes have been developed, compared to two control modes in the last prototype. The current prototype, like the last version, uses an ultrasonic motor as its actuator to enable the patient to do extension and flexion rehabilitation exercises in two degrees of freedom for each finger. Finally, experiments have been carried out to evaluate the performances of this device.

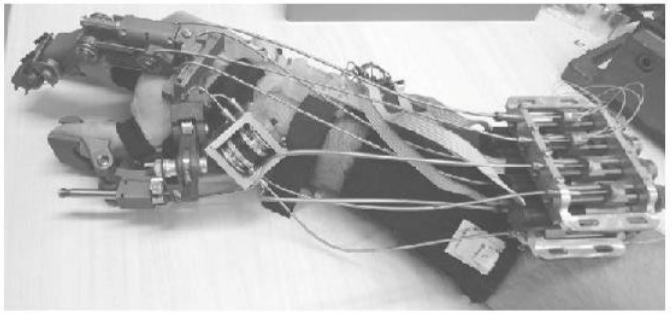
Poster A20

Kinematics and Design of a Portable and Wearable Exoskeleton for Hand Rehabilitation

Marco Cempini, Stefano Marco Maria De Rossi, Tommaso Lenzi, Mario Cortese, Francesco Giovacchini, Nicola Vitiello, Maria Chiara Carrozza: Scuola Superiore Sant'Anna, Italy (SSSA)

- A novel light-weight (500 gs) and anthropomorphic exoskeleton for the hand rehabilitation has been designed and assembled
- Index and thumb module comprise active and passive DoFs, enabling self-alignment of the major human articulations while transmitting torque
- Platform is modular, enabling compliance towards user's anthropometry and hand morphology: design focused on donning-doffing procedures
- Remote tendons-sheats (Bowden-cable) actuation system guarantees wearability and portability, while exploiting under-actuation to implement grasps more simply but still functionally.





Poster A21

A Novel Framework for Virtual Prototyping of Rehabilitation Exoskeletons

Priyanshu Agarwal, Pei-Hsin Kuo, Richard R. Neptune, Ashish D. Deshpande

- Human-model-in-the-loop framework merging musculoskeletal analysis with simulation-based design to iteratively optimize design of rehabilitation exoskeletons.
- Biomechanical, Morphological, and Controller measures to quantify the performance of the device.
- Effective design, control, and experimentation solely by using a virtual prototype.
- Quantitative evaluation of recovery progress is feasible.
- A case study of index finger exoskeleton to illustrate the application of the framework.

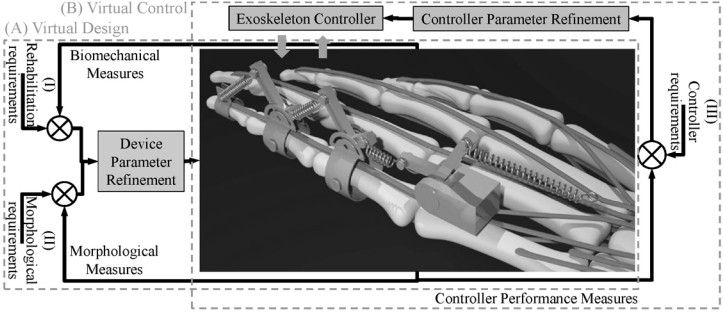


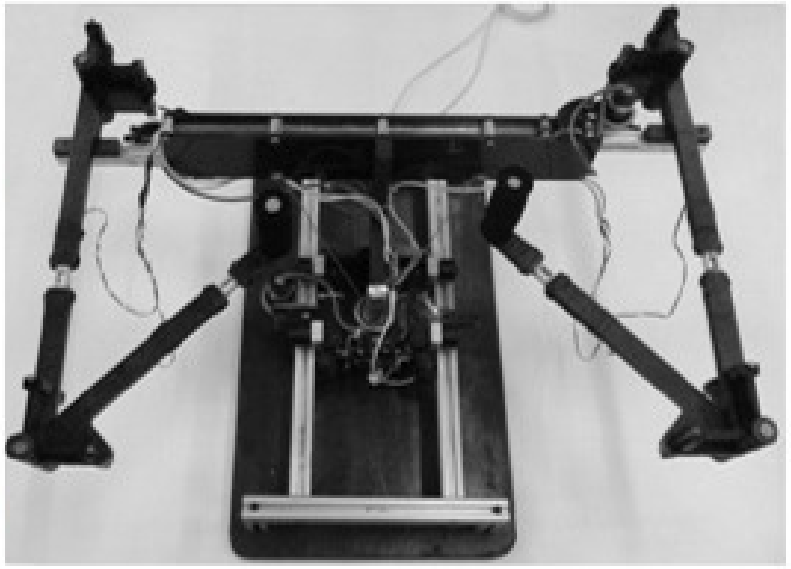
Figure: Framework overview.

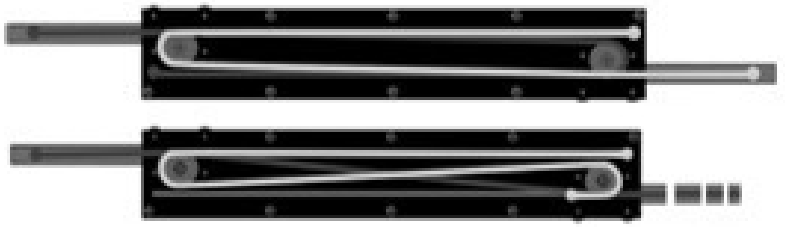
Poster A22

Design and Analysis of A Compliant Bimanual Rehabilitation Device

S McAmis, K B Reed: University of South Florida

- We have developed a compliant bimanual rehabilitation device that couples hands with a variety of coupling stiffnesses, in several easily selectable symmetry modes.
- Preliminary analysis studied bimanual task performance for healthy individuals and a two participant task mimicking hemiparesis.
- Some tasks were easier to complete in visual symmetry.



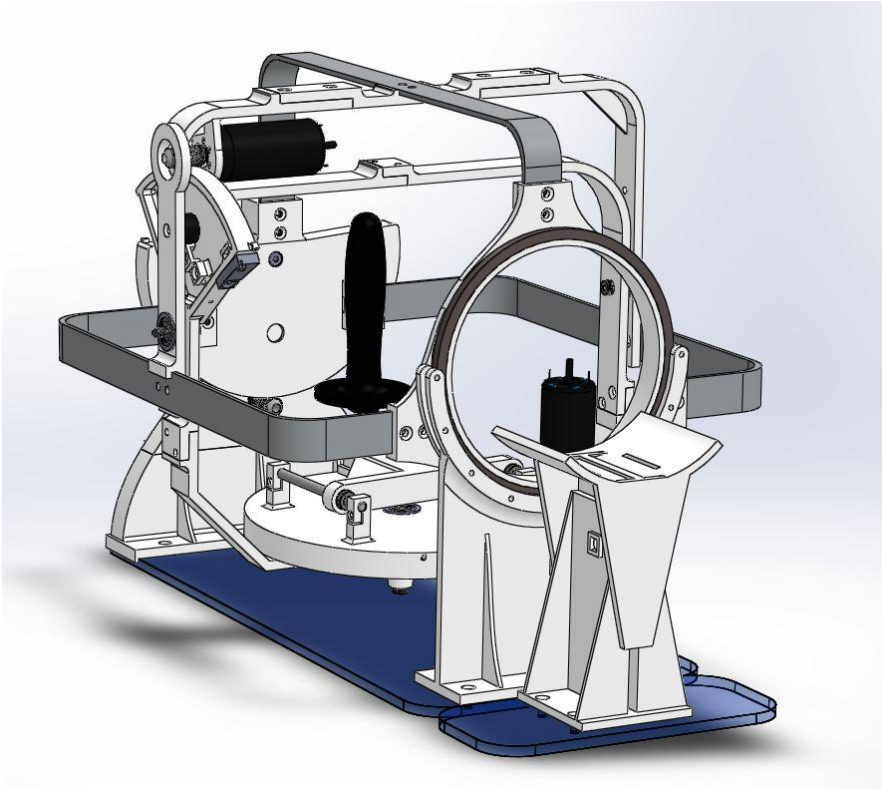


Poster A23

Design of *Wrist Gimbal*: a Forearm and Wrist Exoskeleton for Stroke Rehabilitation

JA Martinez, P Ng, S Lu, MS Campagna, O Celik
San Francisco State University (SFSU)

- A three DOF exoskeleton for forearm and wrist rehabilitation was developed and manufactured.
- Main design goal has been development of a robust, safe and practical device to facilitate clinical implementation, testing and acceptance.



Poster A24

Development of a Fuzzy Logic Based Intelligent System for Autonomous Guidance of Post-stroke Rehabilitation Exercise

R. Huq, R. Wang, E. Lu, D. Hébert, H. Lacheray, and A. Mihailidis

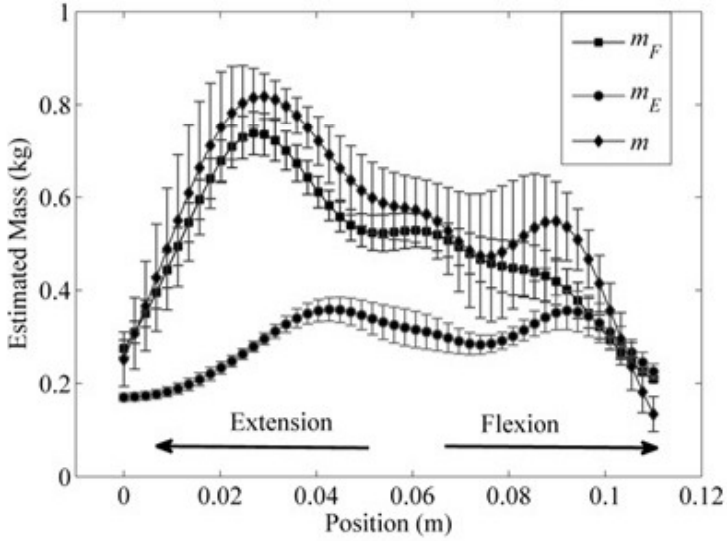
- This work presents preliminary studies in developing a fuzzy logic based intelligent system for autonomous post-stroke upper-limb rehabilitation exercise.
- The intelligent system autonomously varies control parameters to generate different haptic effects on the robotic device. The robotic device is able to apply both resistive and assistive forces for guiding the patient during the exercise.
- The fuzzy logic based decision-making system estimates muscle fatigue of the patient using exercise performance and generates a combination of resistive and assistive forces so that the stroke survivor can exercise for longer durations with increasing control.

Poster A25

Adaptive Control with State-Dependent Modeling of Patient Impairment for Robotic Movement Therapy

C Bower, H Taheri, E Wolbrect: University of Idaho, USA

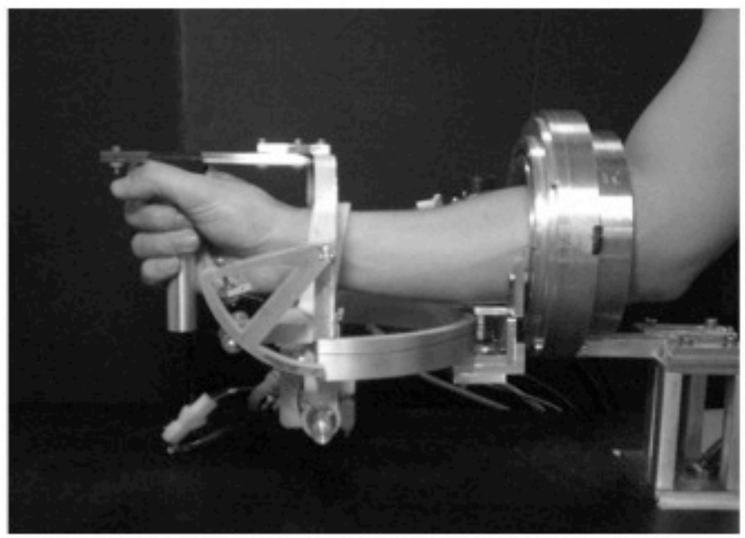
- A state dependent adaptive control approach has been developed for robot-assisted post-stroke therapy
- State dependent impairment modeling allows the robot to better match assistance to patient specific motor deficiencies
- Preliminary experiments using the rehabilitation robot, FINGER, demonstrate the proposed control scheme's ability to match assistance to the current position and direction of the task



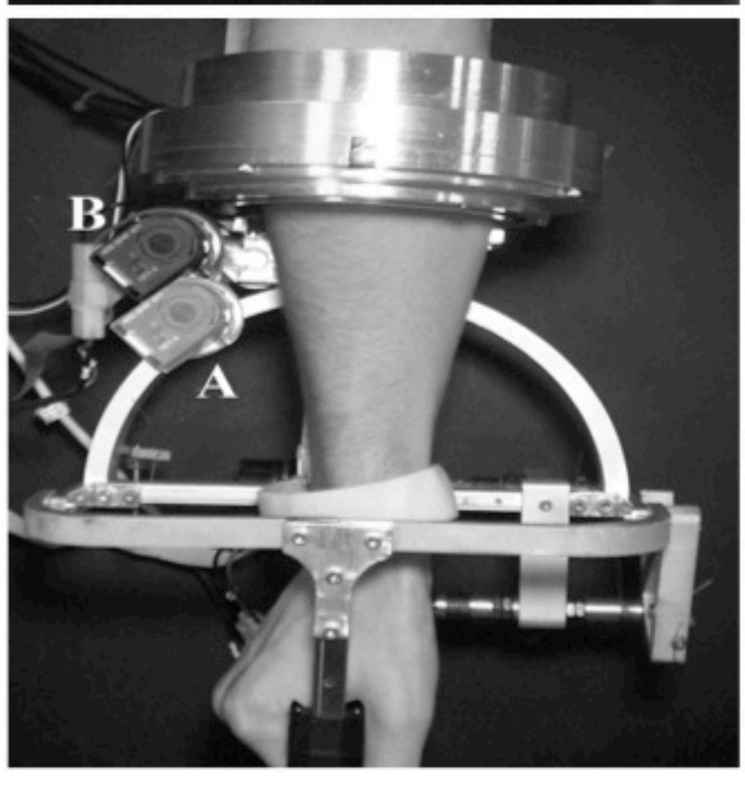
Poster A26

System Characterization of RiceWrist-S: a Forearm-Wrist Exoskeleton for Upper Extremity Rehabilitation

Ali Utku Pehlivan, Chad Rose, and Marcia K. O'Malley



- RiceWrist-S introduces design improvements over a previous prototype
  - Increased torque output
  - Decreased apparent inertia



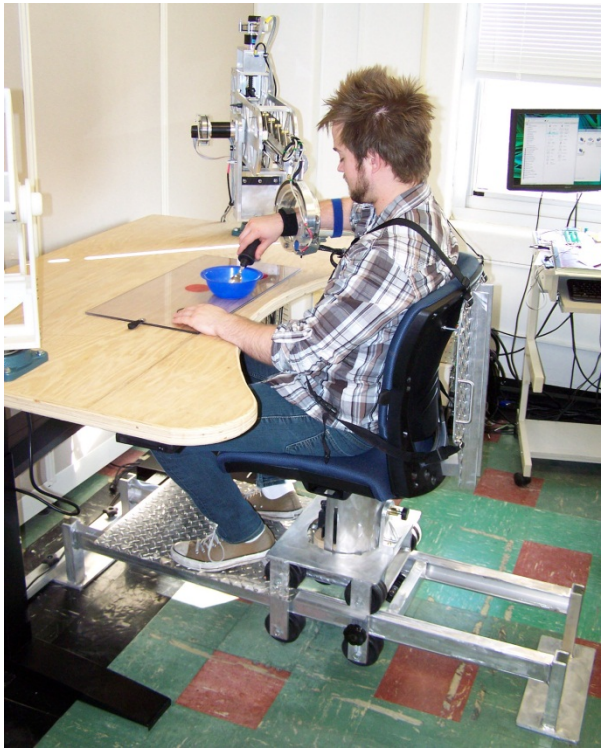
- System characterization investigates and compares with the existing wrist rehabilitation devices:
  - Static friction
  - Inertia and viscous friction element
  - Closed-loop position bandwidth
  - Spatial resolution

Poster A27

Restoring ADL Function after Wrist Surgery in Children with Cerebral Palsy: A Novel Bilateral Robot System Design

MJ Johnson, D Hughes: Medical College of Wisconsin (MCW)
S Kamara, V Anewenter: Milwaukee School of Engineering (MSOE)
A Theriault, D Holley: Marquette University

- A desktop bilateral ADL Exercise Robot has been developed to help children with cerebral palsy recover function for reach and grasp tasks.
- The system consists of a passive robot (6 DOF) and active robot with 7 DOF (5 controlled degrees of freedom)
- Preliminary design results show versatile environment for training reaching and orientation strategies for a variety of ADLs.



Poster A28