Ankle-Knee Prosthesis with Powered Ankle and Energy Transfer for CYBERLEGs α-Prototype.

J. Geeroms, L. Flynn, R. Jimenez-Fabian, B. Vanderborght, D. Lefeber
Department of Mechanical Engineering, Vrije Universiteit Brussel

- An ankle-knee prosthesis has been developed mimicking human gait on level ground.
- The ankle joint is powered to provide the extra necessary energy to provide the same push-off as a healthy ankle.
- Energy that would be dissipated at the knee is transferred to the ankle to provide a push-off torque and reduce the energy the ankle motor has to provide.

Poster D1

Strategies to reduce the configuration time for a powered knee and ankle prosthesis across multiple ambulation modes

AM Simon[1,2], NP Fey[1,2], SB Finucane[1], RD Lipschutz[1,2], LJ Hargrove[1,2]
[1]Rehabilitation Institute of Chicago, USA
[2]Northwestern University, USA

- Configuring a powered knee and ankle prosthesis is challenging.
- Control strategies that either mimic the behavior of biological joints or depend on instantaneous loads within the prosthesis were developed.
- Three transfemoral amputees used the powered prosthesis to walk, ascend/descend a ramp, and ascend/descend stairs using a reciprocal gait.
- These strategies reduced the amount of individually tuned parameters while maintaining similar kinematics to non-amputees across five ambulation modes.

Poster D2

Effects of a powered ankle-foot prosthesis on kinetic loading of the contralateral limb: A case series

David Hill & Hugh Herr
Media Lab
Massachusetts Institute of Technology

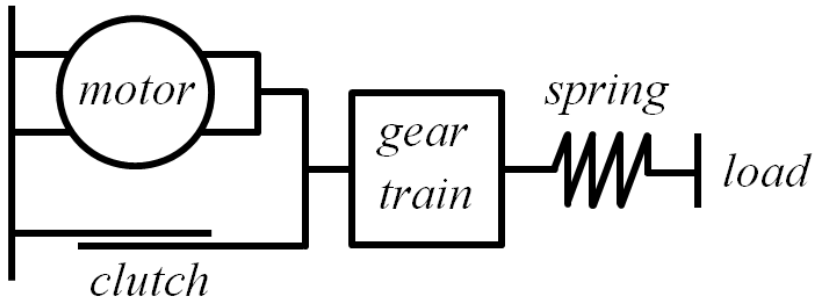
- A comparison between the powered BiOM ankle-foot prosthesis and conventional passive ankle-foot prostheses was conducted to evaluate the effect of prosthetic ankle push-off during late stance on the leading, contralateral leg
- The prostheses were evaluated using six kinetic loading measurements: step-to-step transition work, peak resultant ground reaction force, resultant force loading rate, peak pressure, knee external adduction moment (EAM), and EAM rate
- Preliminary results suggest that more biomimetic prosthetic ankle-foot push-off during late stance may limit contralateral leg musculoskeletal stress in walking

Poster D3

Clutchable Series-Elastic Actuator: Design of a Robotic Knee Prosthesis for Minimum Energy Consumption

E J Rouse, L M Mooney, E C Martinez-Villalpando, H M Herr
Massachusetts Institute of Technology

- A novel modification to the SEA architecture was proposed by adding a clutch in parallel with the motor within the SEA (CSEA).
- Tuned series elasticity was optimized to fit the spring-like torque-angle relationship.
- In simulation, a CSEA prosthetic knee required 70% less electrical energy than a traditional SEA.



EMG Control of a Bionic Knee Prosthesis: Exploiting Muscle Co-Contractions for Improved Locomotor Function

J A Dawley, G D Fulk, K B Fite: Clarkson University, USA

- An architecture for EMG control of knee impedance in a powered transfemoral prosthesis has been developed
- Approach provides performance robustness to variation in EMG co-contraction and electrode placement
- Experimental results for level walking demonstrate consistent and repeatable limb control under full weight-bearing load

Poster D5

Modeling of WalkMECH: a Fully-Passive Energy-Efficient Transfemoral Prosthesis Prototype

Ramazan Unal[1,2], Feite Klijnstra[1], Bram Burkink[1], Sebastiaan Behrens[2],
Stefano Stramigioli[1], Bart Koopman[2] and Raffaella Carloni[1]
Robotics and Mechatronics Engineering Laboratory[1]
Biomechanical Engineering Laboratory[2]
University of Twente, the Netherlands

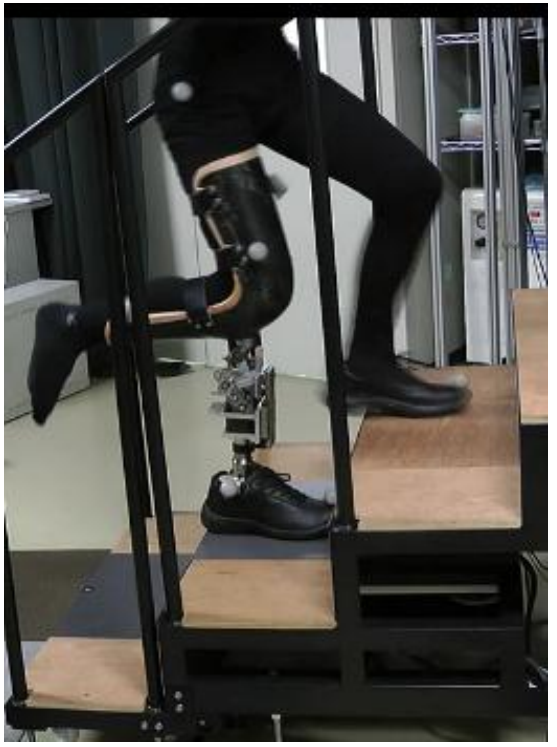
- Energy-efficient fully passive transfemoral prosthesis, WalkMECH is modeled.
- Dynamic model is employed for evaluating the biomechanical performance of WalkMECH.
- Simulation of the model is validated with measurement data from fuctional tests.

Poster D6

Novel Knee Joint Mechanism of Transfemoral Prosthesis for Stair Ascent

K Inoue: Kagawa University, Japan
T Wada: Ritsumeikan University, Japan
R Harada, S Tachiwana: Kagawa University, Japan

- A novel knee joint mechanism was proposed for stair ascent with transfemoral prosthesis without actuators
- Knee flexion-lock and extension functions were designed for stance phase
- Knee extension movement that realized stair ascent was accomplished with positive joint moment power generation transforming potential energy



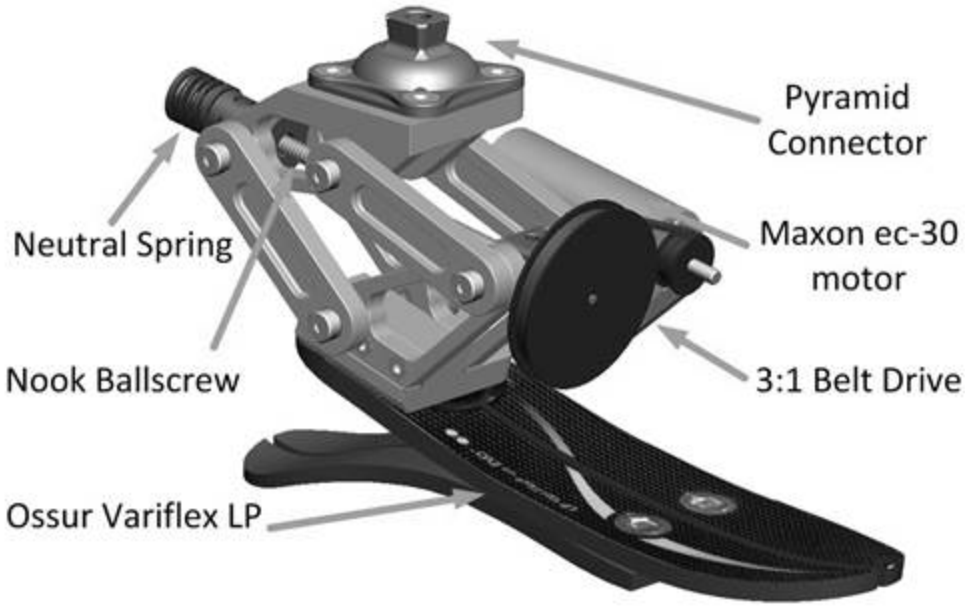
Poster D7

Redefining Prosthetic Ankle Mechanics

Non-Anthropomorphic Ankle Design

A LaPrè, F Sup: University of Massachusetts Amherst

- Loading of conventional prosthetics during stance result in high moment transfer through the socket interface
- High moments cause high pressures on residual limb which can be harmful
- Calculations show that altering shank trajectory throughout stance can decrease moment transferred
- Moment-reducing robotic test prosthesis has been designed

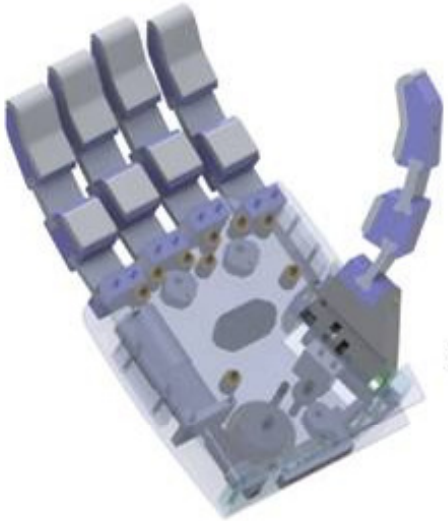


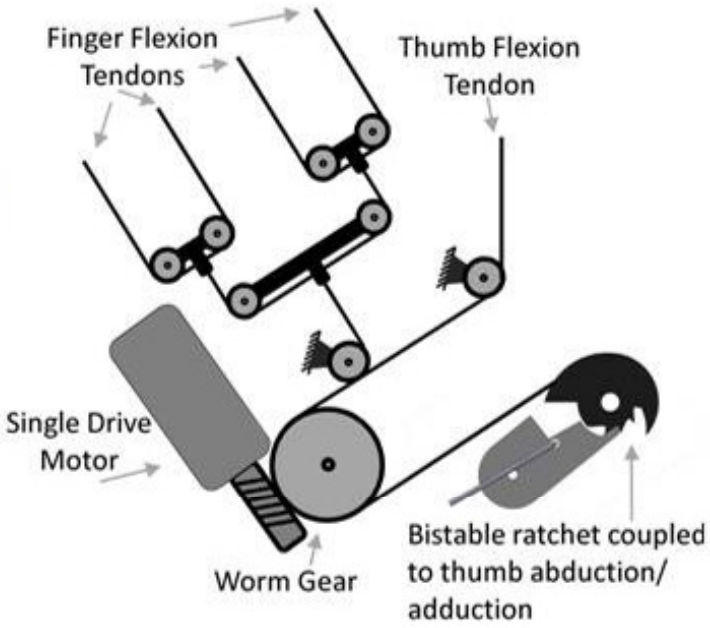
Poster D8

Novel Differential Mechanism Enabling Two DOF from a Single Actuator: Application to a Prosthetic Hand

Joseph T. Belter, and Aaron M. Dollar
Yale University, USA

- We presents a novel method of increasing the range of achievable configurations of a mechatronic hand controlled by a single actuator.
- The mechanical coupling scheme is demonstrated in a prototype hand with results showing a decrease in weight but an increase in transition time between grasps as compared to a two-actuator system.



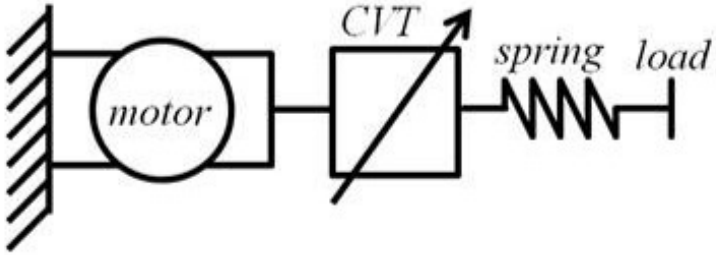


Poster D9

Continuously-Variable Series-Elastic Actuator

L M Mooney, H M Herr: Massachusetts Institute of Technology, US (MIT)

- A continuously-variable series-elastic actuator (CV-SEA) is presented as an efficient actuator for legged locomotion.
- The CV-SEA allows the motor to operate in speed regimes of higher efficiency.
- Simulations suggest that a CV-SEA will require less energy than a direct drive or SEA when used in a knee prosthesis during level-ground walking.



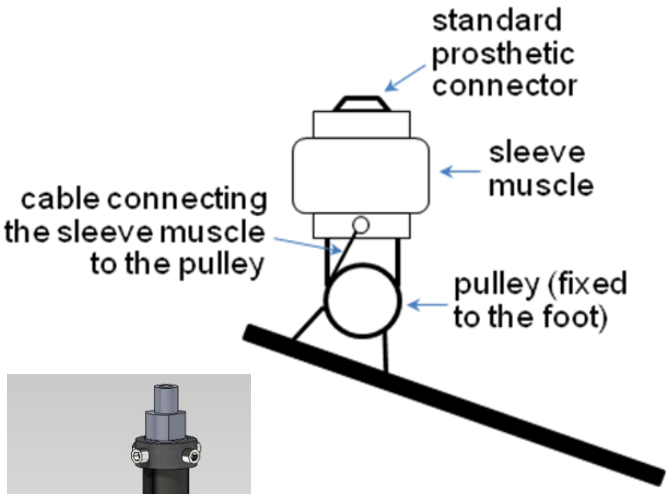
The CV-SEA consists of three elements in series: an electromagnetic motor, a CVT and finally an elastic element. The series elastic element can reduce motor work, increase actuator efficiency and power, and limit motor/transmission shock, while the CVT can further optimize the speed profile of the motor for greater actuator efficiency.

Poster D10

Sleeve Muscle Actuator and Its Application in Transtibial Prostheses

Hao Zheng and Xiangrong Shen
Department of Mechanical Engineering
The University of Alabama

- This paper describes the concept of a new sleeve muscle actuator, and a transtibial prosthesis design powered by this novel actuator.
- Sleeve muscle is an advanced form of the traditional pneumatic muscle, with improved actuation performance and the potential for the integration of the actuator with the load-bearing structure.
- The sleeve muscle-actuated transtibial prosthesis is able to generate the desired torque output within a compact form factor.

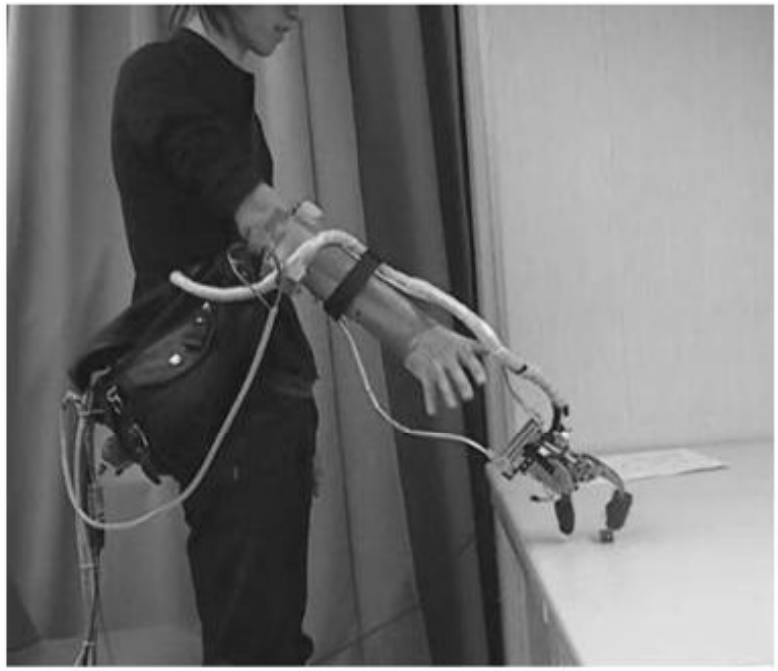


Poster D11

Multimodal Sensor Controlled Three Degree of Freedom Transradial Prosthesis

Kengo Ohnishi: Tokyo Denki University, Japan(TDU)
Toshiyuki Morio, Tomoo Takagi: Okayama Prefectural University, Japan (OPU)
Isamu Kajitani: National Inst. of Adv Industrial Sci. & Tech., Japan (AIST)

- An multifunction myoelectric prosthesis controller is developed with an additional accelerometer to compute the angles of the gravitational force and drive the pro-/spination and palmar-/dorsifelxion motors of the wrist joint.
- Preliminary results illustrate the potential for offering reduced compensative shoulder abduction movement.

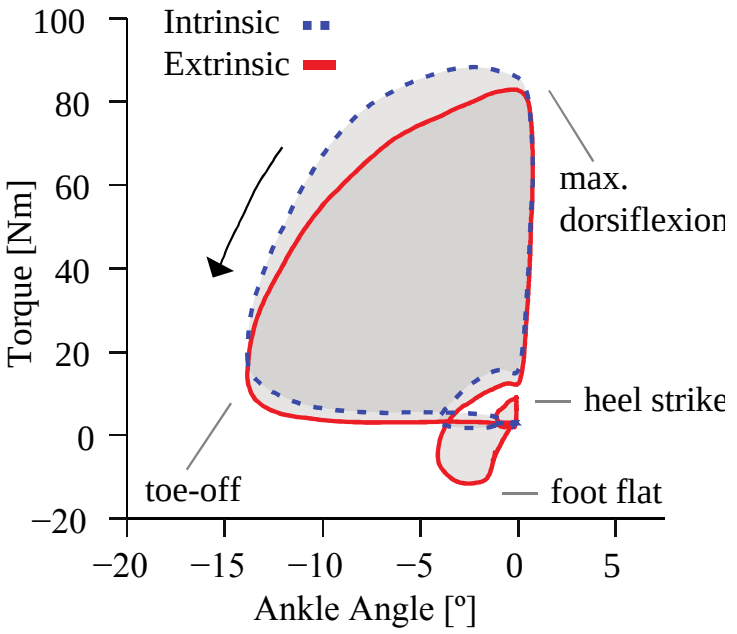


Poster D12

Proportional EMG Control of Ankle Plantar Flexion in a Powered Transtibial Prosthesis

J Wang, OA Kannape, HM Herr
MIT Media Lab, Massachusetts Institute of Technology

- We developed a volitional electromyographic controller to directly modulate plantar flexion in a powered ankle-foot prosthesis—denoted extrinsic controller.
- Preliminary data suggest a transtibial amputee is able to modulate key gait parameters across a wide range of walking speeds using the extrinsic EMG controller.
- Toe-off angle, net ankle work and peak power are equivalent to a biomimetic intrinsic (no EMG) controller on the same prosthesis.



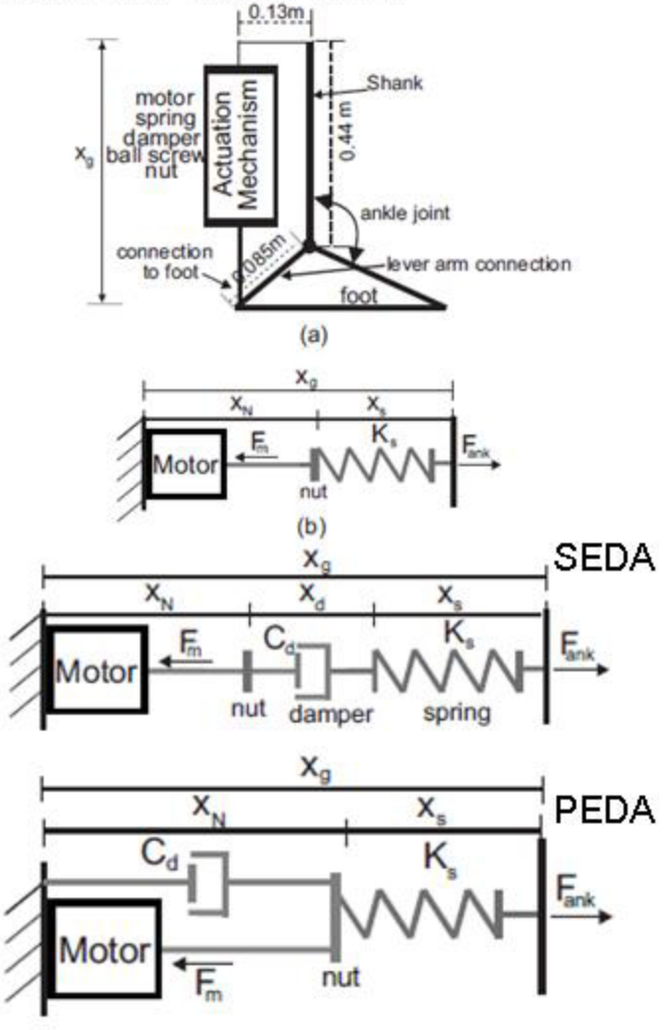
Poster D13

Does it pay to have a damper in a powered ankle prosthesis? A Power-Energy Perspective

Mahdy Eslamy[1,2] Martin Grimmer[1], Stephan Rinderknecht[2], Andre Seyfarth[1]

[1]Lauflabor Locomotion Laboratory, Technical University of Darmstadt,64289, Germany,
[2]Institute for Mechatronic Systems in Mechanical Engineering (IMS), Technical University of Darmstadt, 64287, Germany, email to: eslamy@ims.tu-darmstadt.de

- In this paper we investigated on peak power (PP) and energy (ER) requirements for different active ankle actuation concepts that can have both elasticity and damping characteristics.
- For SEA (series elastic actuator), SEDA and PEDA, we calculated the required minimum motor PP and ER in different human gaits: normal level walking, ascending and descending the stairs.
- We found that for level walking and ascending the stairs, the SEA concept, and for descending, the SEDA, were the favorable concepts to reduce required minimum PP and ER in comparison to a DD (direct drive) concept. In SEDA concept, the minimum PP could be reduced to half of what SEA would require.
- Nevertheless, it was found that spring was always required, however damper showed 'task specific' advantages. As a result, if a simple design perspective is in mind, from PP-ER viewpoint, SEA could be the best compromise to be used for different above-mentioned gaits. For SEDA or PEDA concepts, a controllable damper should be used.
- In addition, our results show that it is beneficial to select spring stiffness in SEA, based on level walking gait. The PP and ER requirements would increase very slightly for stairs ascending, and to some extent (10.5%) for descending as a consequence of this selection.



Poster D14

Myoelectric Neural Interface Enables Accurate Control of a Virtual Multiple Degree-of-Freedom Foot-Ankle Prosthesis

D.C. Tkach, R.D. Lipschutz, S.B.Finucane, L.J. Hargrove, *Rehabilitation Institute of Chicago, Chicago IL, US*

- EMG was collected from below-knee and above-knee muscles of 12 amputee and 5 control subjects
- LDA pattern recognition classifier predicted ankle *rotation*, *in/eversion* and *dorsi/plantaflexion* from recorded EMG, in real-time
- Results demonstrate that a 3-DOF foot-ankle prosthesis can be accurately controlled via a surface EMG neural interface
- Residual leg movement does not affect accuracy of ankle movement classification

Poster D15

Pattern Recognition of Hand Movements with Low Density sEMG for Prosthesis Control Purposes

J.J. Villarejo, J.F. Sarmiento, A. Frizera, T.F. Bastos: PPGEE, RENORBIO, Universidade Federal do Espírito Santo (UFES), Vitoria (Brazil)

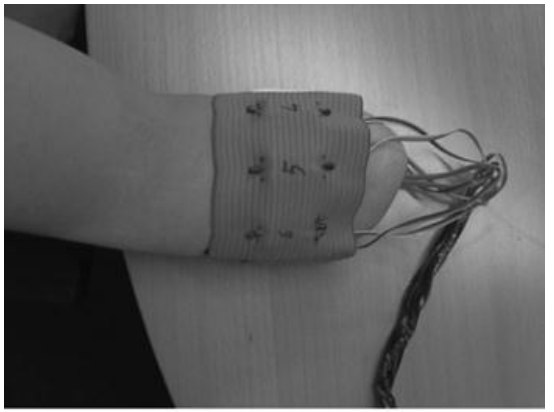
- A classification system based on sEMG has been evaluated to control a multifunctional hand prosthesis
- Different kinds of hand and wrist gestures were studied, considering low-density and low-level sEMG contractions
- The results showed up to 95.4% of recognition success for different groups of proposed gestures

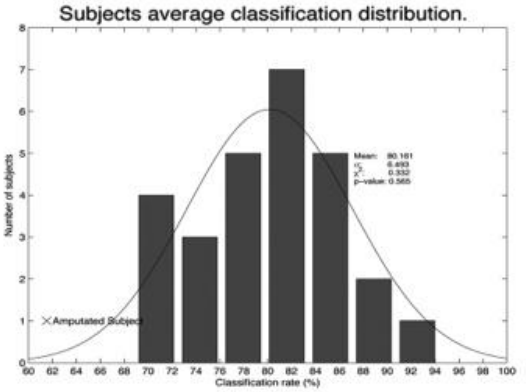
Poster D16

Recognition of Hand Movements in a Trans–Radial Amputated Subject by sEMG

Manfredo Atzori (HES-SO Valais)
Henning Müller (HES-SO Valais)

- The Ninapro acquisition protocol for sEMG control of hand prosthetics was tested on an amputated subject.
- Preliminary results show 61.51% of classification accuracy over 53 movements and the possibility to classify 13 movements without any misclassification.
- Results confirmation would be important for the progress of prosthetics natural control.



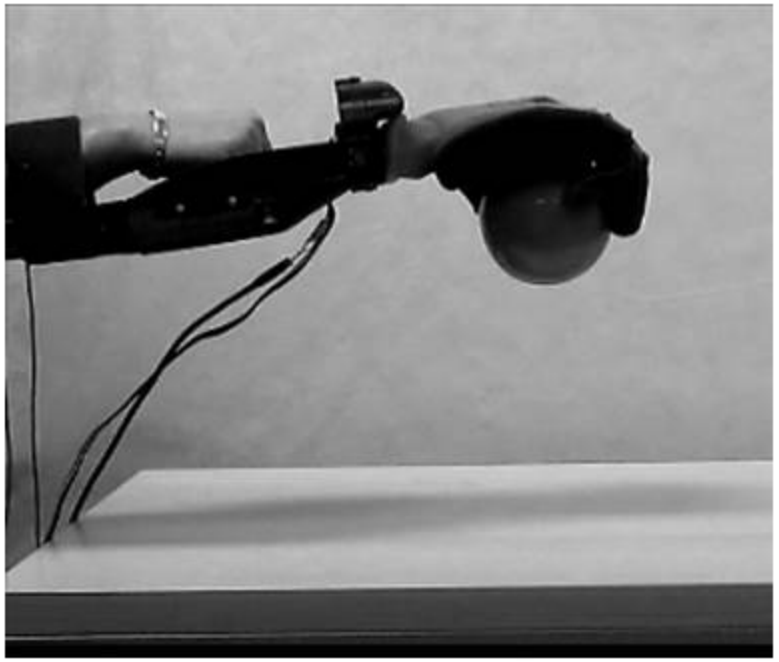


Poster D17

A synergy-driven approach to a myoelectric hand

S.B. Godfrey, A. Ajoudani, M. Catalano, G. Grioli, A. Bicchi

- The Pisa/IIT SoftHand uses synergies to grasp a wide variety of objects
- Myoelectric control of impedance and position information as well as vibrotactile feedback were evaluated
- Preliminary results suggest benefits of incorporating synergies in the hardware design of myoelectrics and decreased physical and cognitive burden with impedance control and feedback.

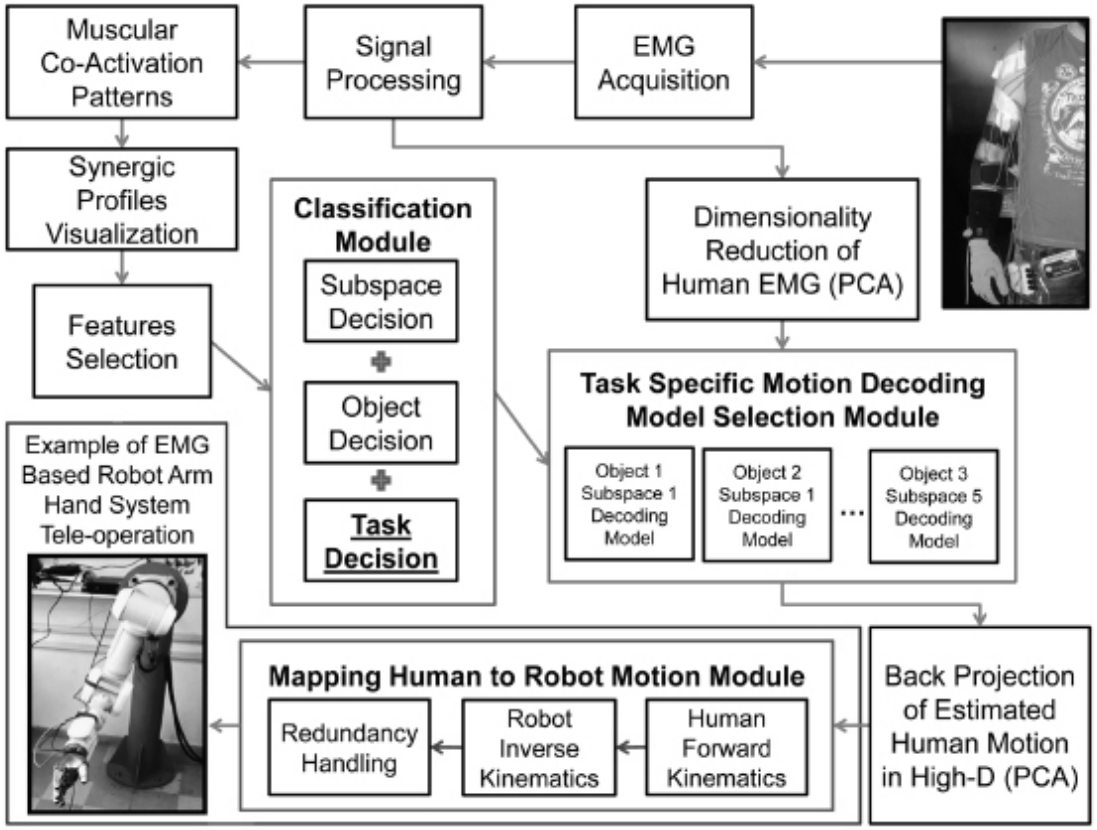


Poster D18

Task Discrimination from Myoelectric Activity: A Learning Scheme for EMG-Based Interfaces.

Minas V. Liarokapis[1], Panagiotis K. Artemiadis[2] and Kostas J. Kyriakopoulos[1]
[1]Sch. of Mechanical Eng., National Technical Univ. of Athens, Greece
[2]Sch. for Eng. of Matter, Transport and Energy, Arizona State Univ., USA

- A learning scheme based on Random Forests is used, to discriminate the task to be executed using only myoelectric activity from the upper limb.
- Three different task features can be discriminated: subspace to move towards, object to be grasped and task to be executed (with the object).
- Random Forests perform efficient features selection, helping us to reduce the number of EMG channels required for task discrimination.
- The proposed scheme can be used by a series of EMG-based interfaces

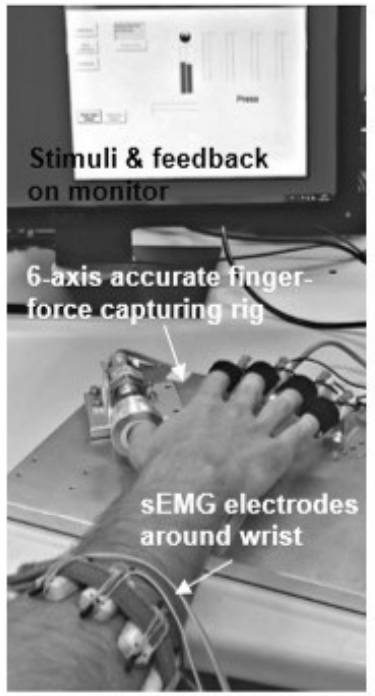


Poster D19

Evaluating subsampling strategies for sEMG-based prediction of voluntary muscle contractions

R. Kõiva: Bielefeld University, Germany
B. Hilsenbeck, C. Castellini: DLR - German Aerospace Center, Germany

- We apply an SVM to surface electro-myography (sEMG) signals to predict muscle contractions;
- In an online setting, due to computational limits, a strategy to bound the training data is required;
- We compare various subsampling strategies in an experiment involving 10 able-bodied participants;
- Two subsampling strategies achieve results comparable to those obtained on the entire dataset suggesting online training is feasible.

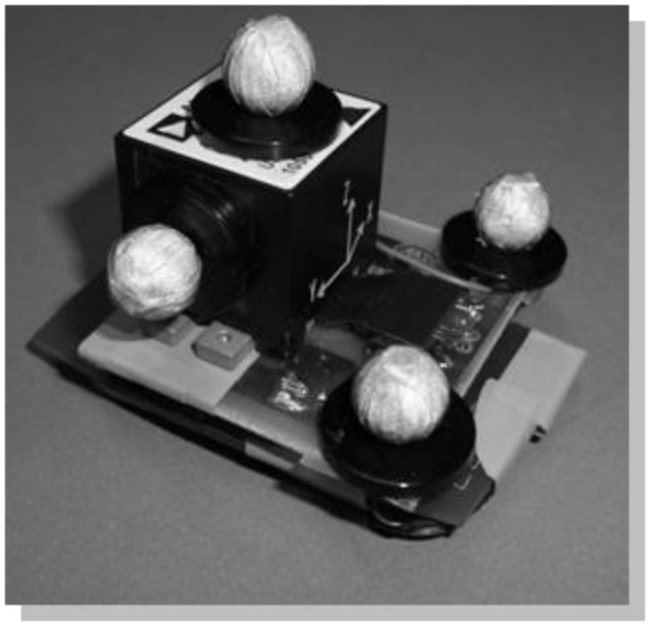


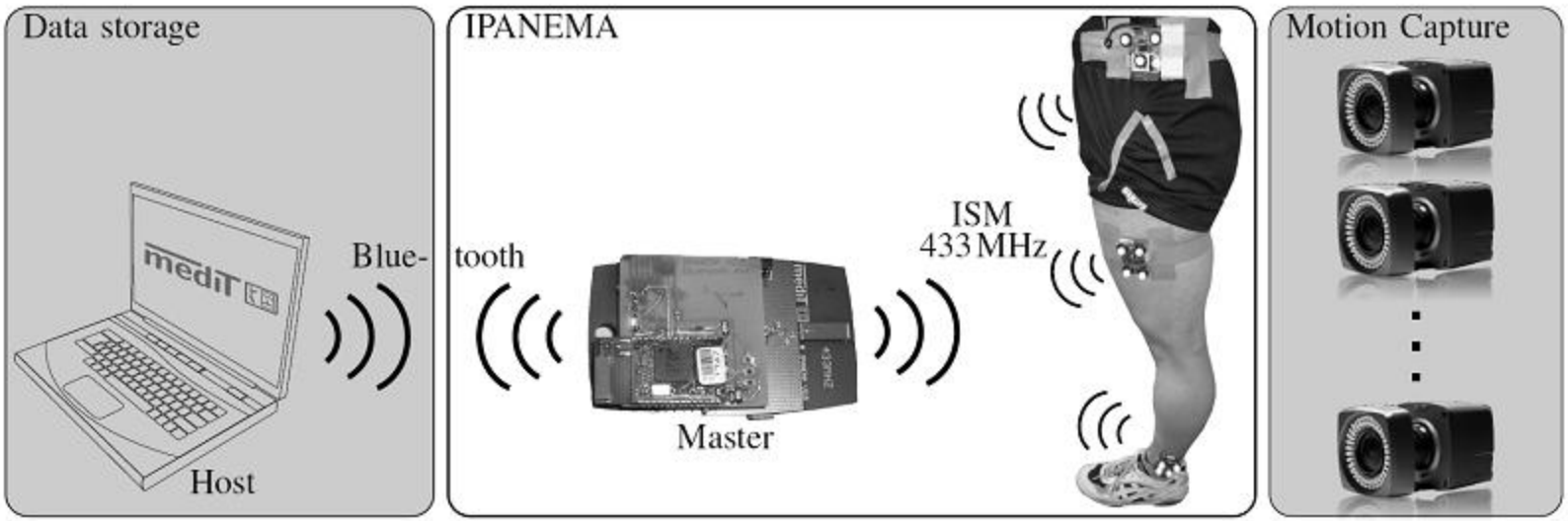
Experimental setup to validate our approach

Poster D20

Body sensor network-based strapdown orientation estimation: Application to human locomotion

- Body sensor network application using 9DOF measurement unit
- Bias free filtering with EKF-QUEST and novel complementary sliding mode observer including QUEST-algorithm
- Treadmill walking validation and motion tracking reference comparison
- Good performance with both filters of reduced calculation cost and strapdown body segment tracking application





Poster D21

Design of a Wearable Perturbator for Human Knee Impedance Estimation during Gait

MR Tucker, A Moser, O Lambercy, J Sulzer, R Gassert
ETH Zurich, Switzerland

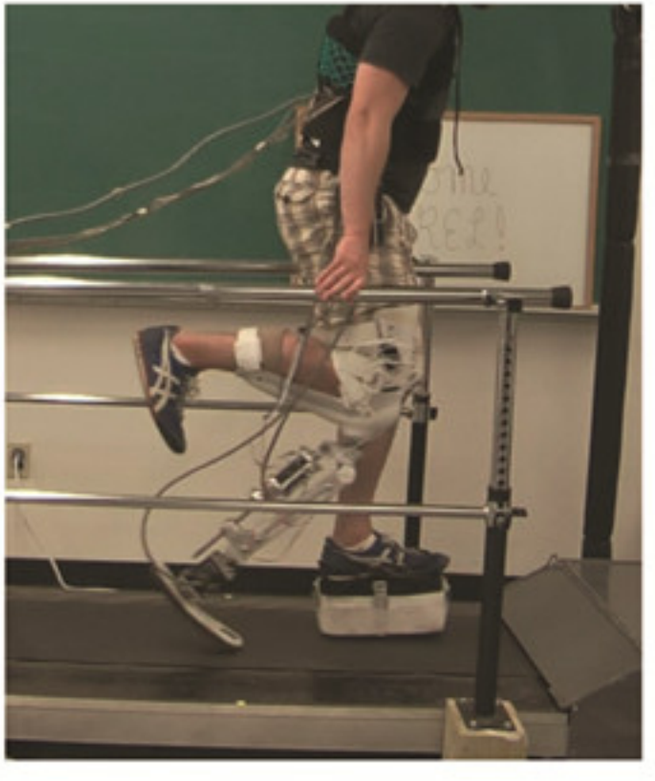
- Remotely actuated knee brace for experimental biomechanic study
- Applies velocity perturbations while measuring torque
- Custom hinge, clutch, actuation, and sensor designs

Poster D22

Design of An Expert System to Automatically Calibrate Impedance Control for Powered Knee Prostheses

Ding Wang, Ming Liu, Fan Zhang, He Huang: University of Rhode Island (USA)

- An expert system was designed based on fuzzy logic inference (FLI) to match the desired knee motion and gait timing while the user walking with powered knee prostheses (PKP).
- The developed system was validated on an able-bodied subject wearing our designed PKP.
- Preliminary experimental results demonstrated that the developed expert system can converge the user's knee profile and gait timing to the desired values within 2 minutes.
- After the auto-tuning procedure, the user produced more symmetrical gait.

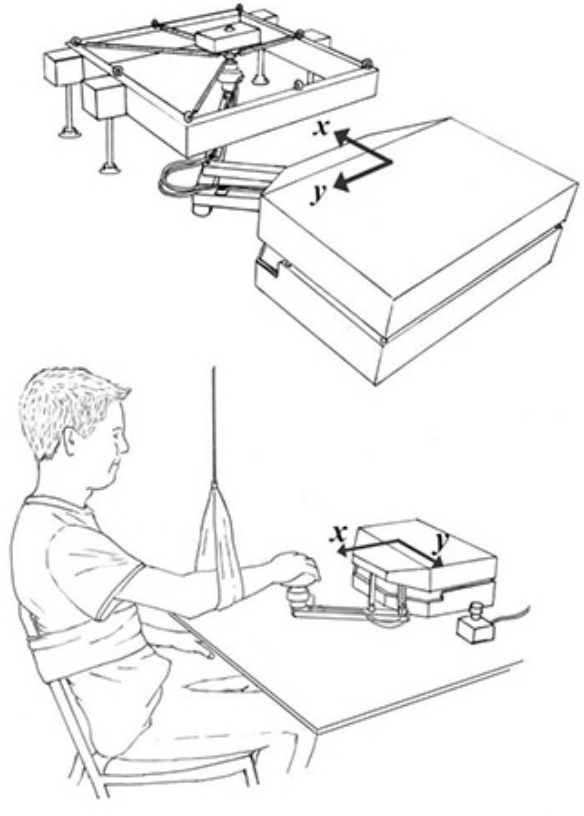


Poster D23

Measuring the Dynamic Impedance of the Human Arm Without a Force Sensor

Matthew Dyck and Mahdi Tavakoli
University of Alberta, Canada

- The high retail cost of many rehabilitation robotic systems has posed a barrier to their widespread clinical use
- We present a technique to accurately measure arm impedance in which a conventional, costly force sensor is replaced by an inexpensive accelerometer
- Methods are validated on a mass-spring system of known impedance and applied to data from the human arm

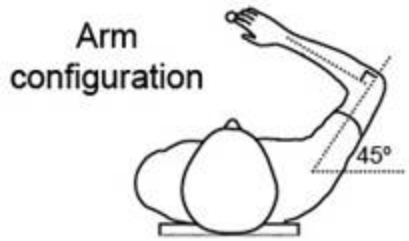


Poster D24

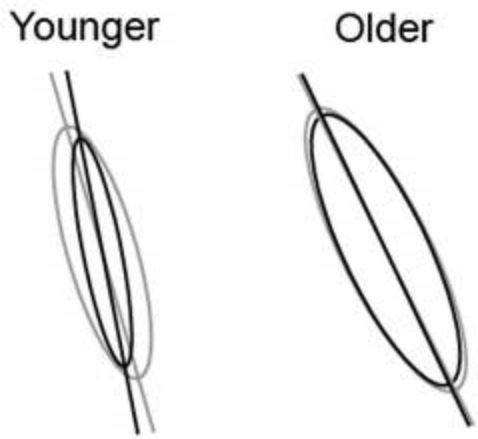
Effect of Age on Stiffness Modulation During Postural Maintenance of the Arm

TL Gibo: Johns Hopkins University
AJ Bastian: Kennedy Krieger Institute; Johns Hopkins School of Medicine
AM Okamura: Stanford University

- Limb stiffness can be tuned via selective muscle co-contraction to maintain stability during tasks, while balancing metabolic cost
- Subjects kept their hand in a target while a robot applied two types of directional force perturbations
- Older individuals showed minimal stiffness modification between the two perturbation conditions compared to younger individuals
- Evaluation of activities of daily living or skill assessment in older populations should consider this impairment in motor control



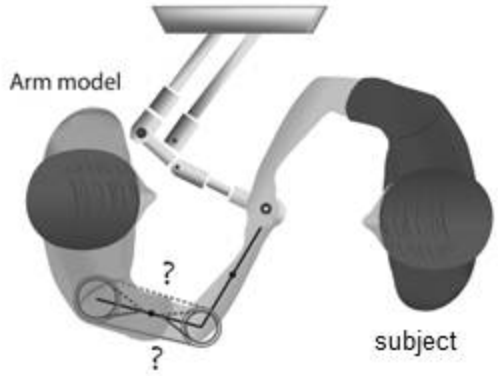
Stiffness ellipse



Poster D25

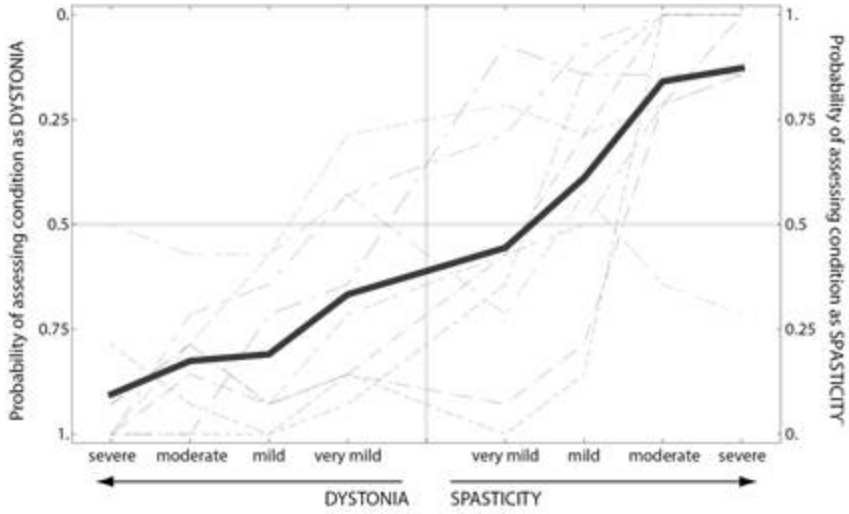
Haptic recognition of dystonia and spasticity in simulated multi-joint hypertonia

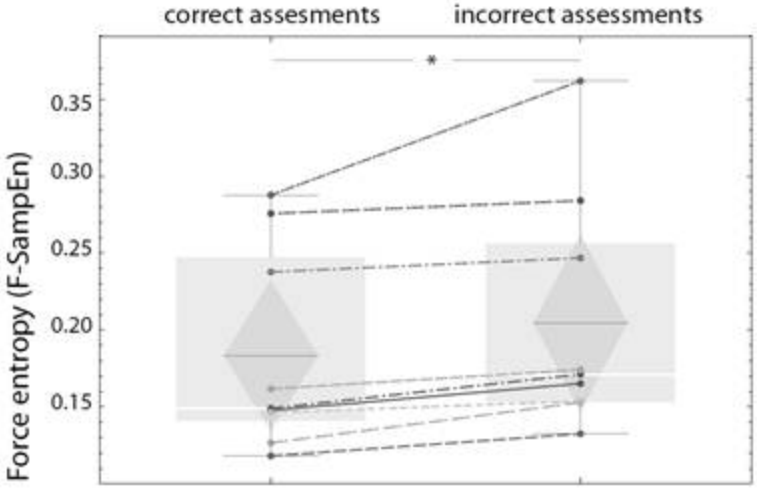
D. Piovesan*, A. Melendez-Calderon*, F.A. Mussa-Ivaldi * equal contribution



We developed a physical simulator to test the capability of naïve subjects to recognize dystonic-like and spastic-like symptoms.

Subjects have a low sensitivity to differentiate between dystonia and spasticity





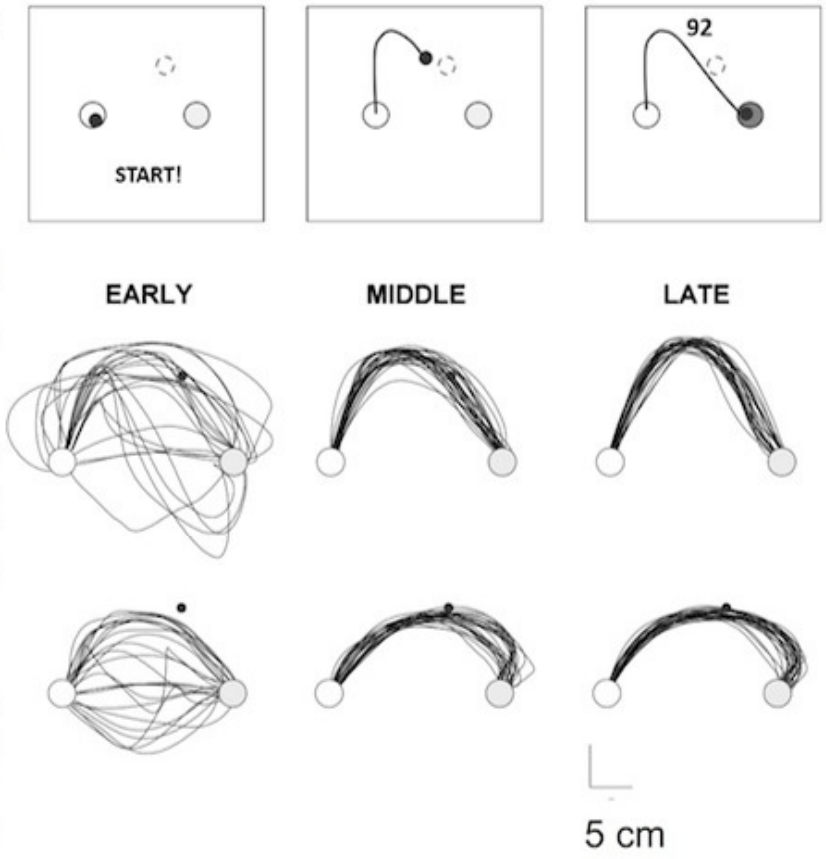
physical manipulation characterized by high *sample entropy* in force can lead to a misjudgment of the impairment

Poster D26

Reward-based learning of a redundant task

Irene Tamagnone, Maura Casadio and Vittorio Sanguineti
Dept Informatics, Bioengineering, Robotics and Systems Engineering
University of Genoa

- **Goal**: Capture common trends in the strategies subjects use in the exploration of the task space and in the exploitation of the task redundancy during learning
- **Experiment**: Subjects performed point-to-point movement, in which start and target positions were fixed and visible, but the score provided at the end of the movement depended on the distance of the trajectory from a hidden via-point. Subjects don't have clues on task solution other than the score value
- **Analysis**: Look at trial by trial evolution of score and trajectories similarity and at the evolution of movement variability at different fractions of the path length



Poster D27

Adaptation to Visuomotor Rotation in Isometric Reaching is Similar to Movement Adaptation

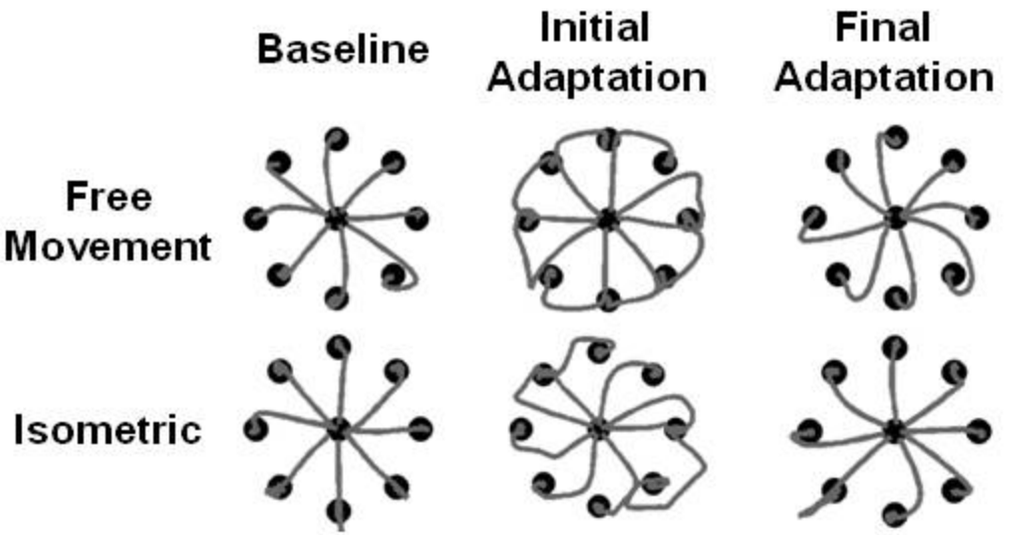
Michele F. Rotella*, Margaret Koehler*, Ilana Nisky*, Amy J. Bastian†, Allison M. Okamura*

*Dept. of Mechanical Engineering, Stanford University, Stanford, CA

†Kennedy Krieger Inst. and Dept. of Neuroscience, Johns Hopkins University, Baltimore, MD

- Isometric reaching, in which user-applied force is used to control a virtual cursor, may be useful in rehabilitation
- The rate and extent of adaptation to a visuomotor rotation for position and velocity isometric mappings is similar to adaptation in movement

Experimental setup for planar reaching

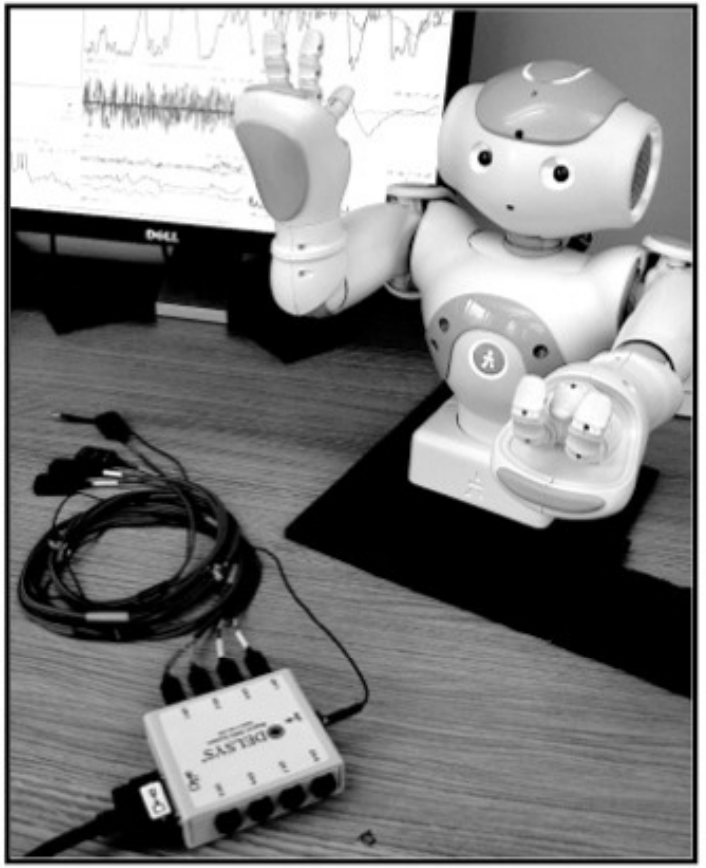


Poster D28

Real-time Prediction Learning for the Simultaneous Actuation of Multiple Prosthetic Joints

PM Pilarski, TB Dick, RS Sutton: University of Alberta (CAN)

- A preliminary study integrating learned real-time predictions into a multi-joint prosthesis controller.
- Results indicate that an integrated approach may speed control learning, allow unsupervised adaptation in myoelectric controllers, and facilitate synergies in highly actuated limbs.
- Potential for intuitive joint control of complex prostheses by amputees.



Poster D29