The Brain Initiative: a Robotics Perspective

Matei Ciocarlie

slide credit:

Sunil Agrawal

Peter Allen

IEEE RAS Society

COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

What is Robotics?

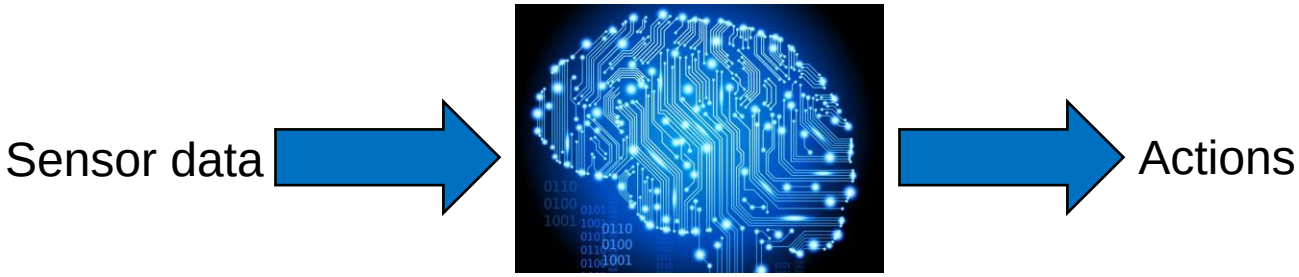
- From the IEEE RAS:
  - **Robotics** focuses on systems incorporating sensors and actuators that operate autonomously or semi-autonomously in cooperation with humans. Robotics research emphasizes intelligence and adaptability to cope with unstructured environments.
  - **Automation research e**mphasizes efficiency, productivity, quality, and reliability, focusing on systems that operate autonomously, often in structured environments over extended periods, and on the explicit structuring of such environments.

What is Robotics?

The science of **effecting change on the world**

What is Robotics?

The science of **effecting change on the world**



- Newborn animals do not develop meaningful sensing capabilities without simultaneously learning self-locomotion [Held & Hein 1963]
- You have truly understood a system when you can reproduce it
  - versatility in interacting with the physical world

Brain Science and Robotics

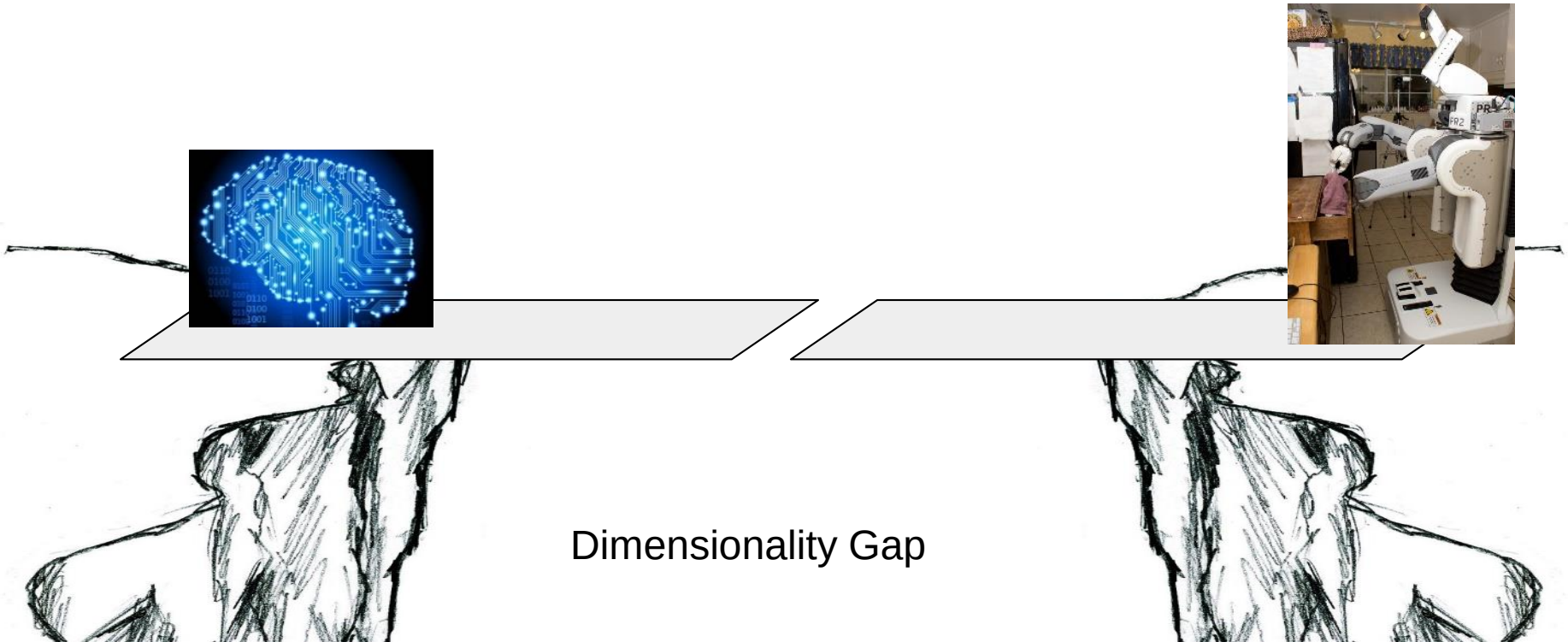
- Robots controlled by BMI / BCI
- The brain as inspiration for Robotics
  - learning (reinforcement learning, deep learning, etc.)
  - many other examples
- Robotics as inspiration for understanding the brain
  - computational modeling tools
  - … or even “simple” feedback and feedforward control
- Rehabilitation robotics
  - using robots to understand and promote motor (re-)learning

BMI / BCI Control

Environment interaction is inherently complex

- many DOF of both the platform and the environment

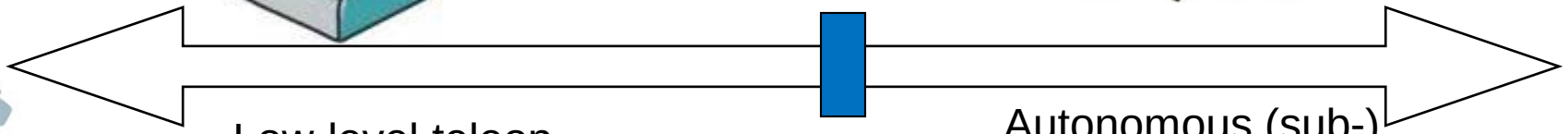
BMI interfaces provide too few (or too many!) signals.



Dimensionality Gap

Shared Autonomy

- Combine **robot capabilities** with **human cognition**
  - teleoperation to autonomy: a continuous spectrum rather than a binary choice



Low-level teleop
when needed

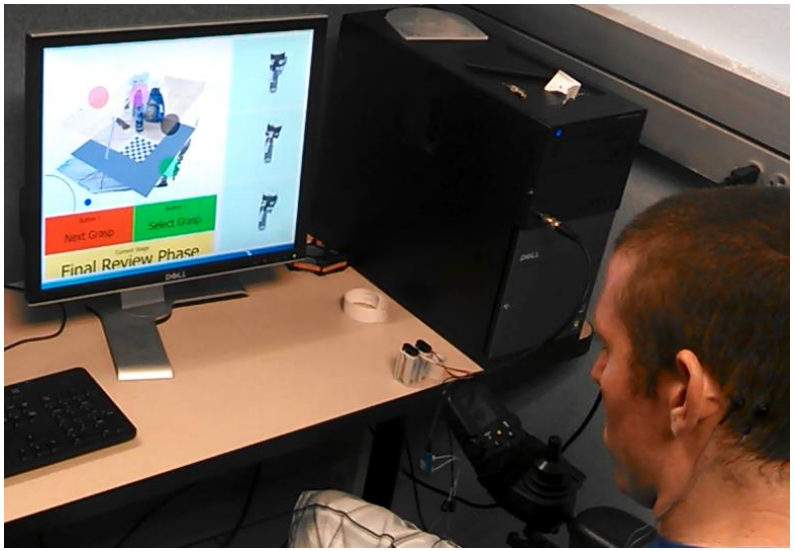
Autonomous (sub-)
tasks when possible

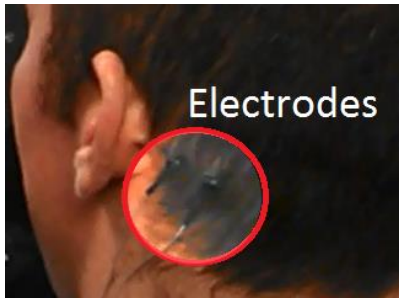
Assistive Robotics for Grasping and Manipulation Using a Novel sEMG Interface

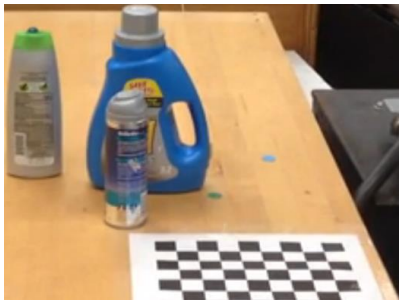
NRI Collaborative Research:
Peter K. Allen, Columbia University
Sanjay Joshi, UC Davis

Human-in-the-Loop Grasping with Online and Offline Planning Using Noisy, Low Bandwidth Inputs

- Online shared control grasp planner [1]
- Offline Grasp Database [2]
- Integrated vision system [3]
- Novel behind the ear SEMG input device.[4]
- Human subject validation

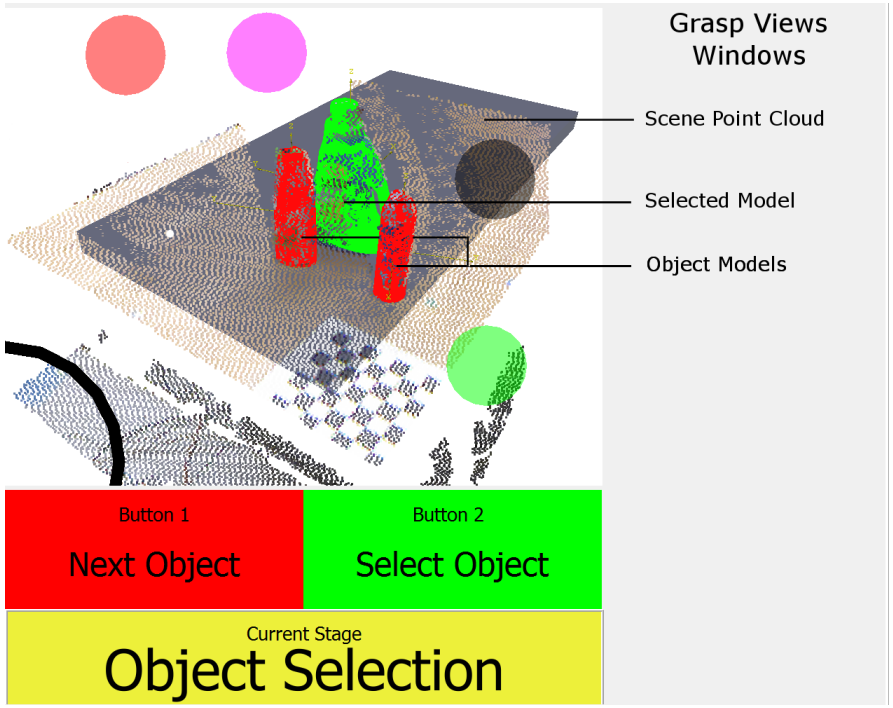


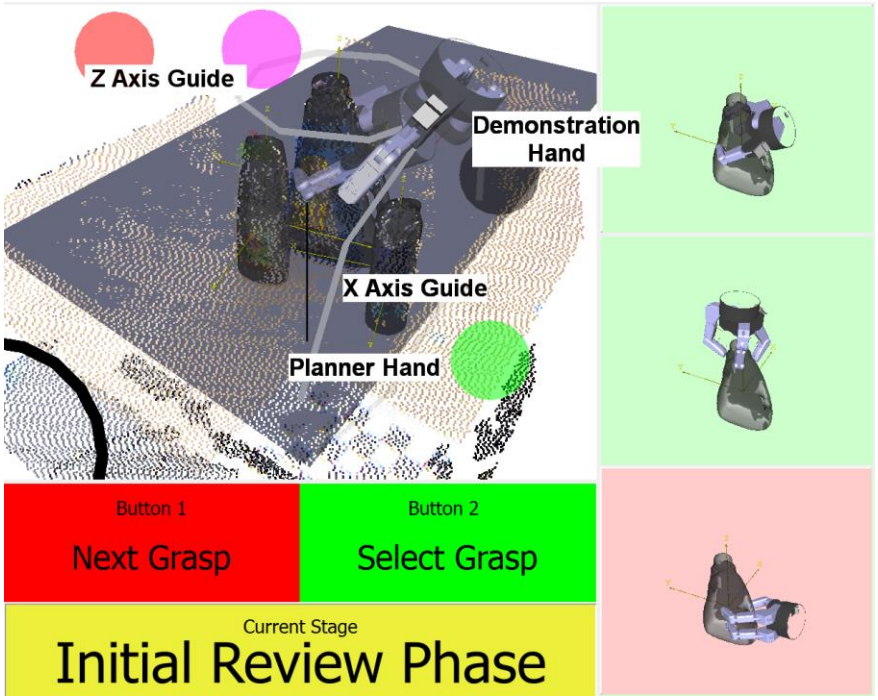




[1] - Ciocarlie and Allen, "Hand posture subspaces for dexterous robotic grasping," IJRR
[2] - Goldfeder and Allen, "Data-Driven Grasping," *Autonomous Robots 31.1, 2011*
[3] - Papazov and Burschka, "An efficient ransac for 3d object recognition in noisy and occluded scene - ACCV 2011
[4] -S. Vernon and S. S. Joshi, "Brain-muscle-computer interface: mobile-phone prototype development and testing." IEEE Transactions Information Technology 2011.

Grasp Planning Interface

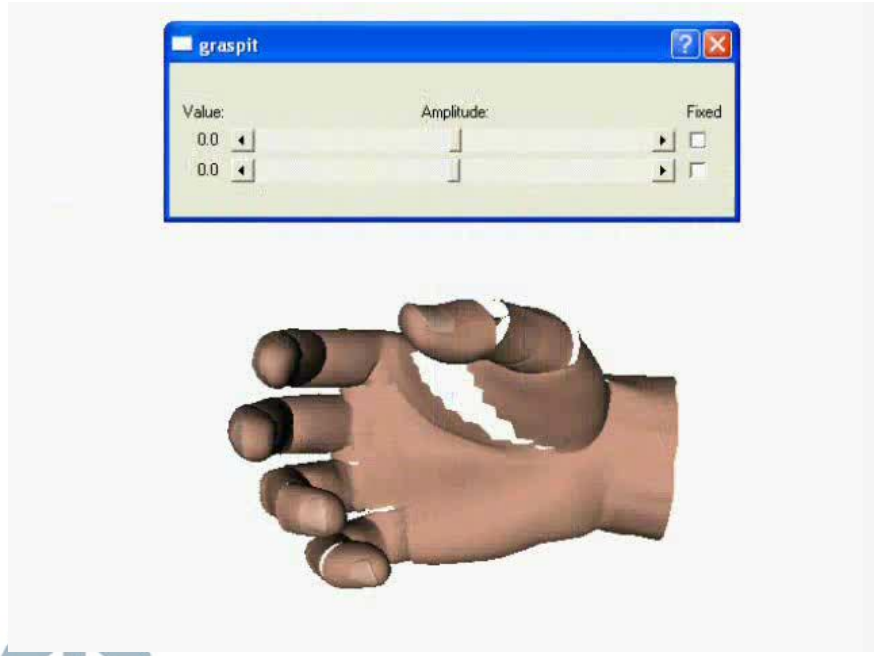


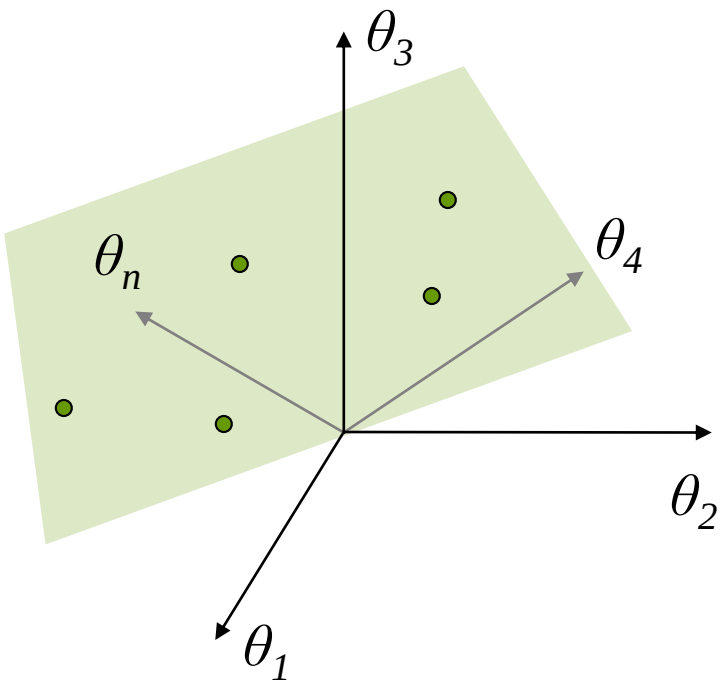


all

Learning from the Human Brain

- How do people simplify hand posture selection?
  - 2 Principal Components account for 85% of the variance! [Santello et al. '98]

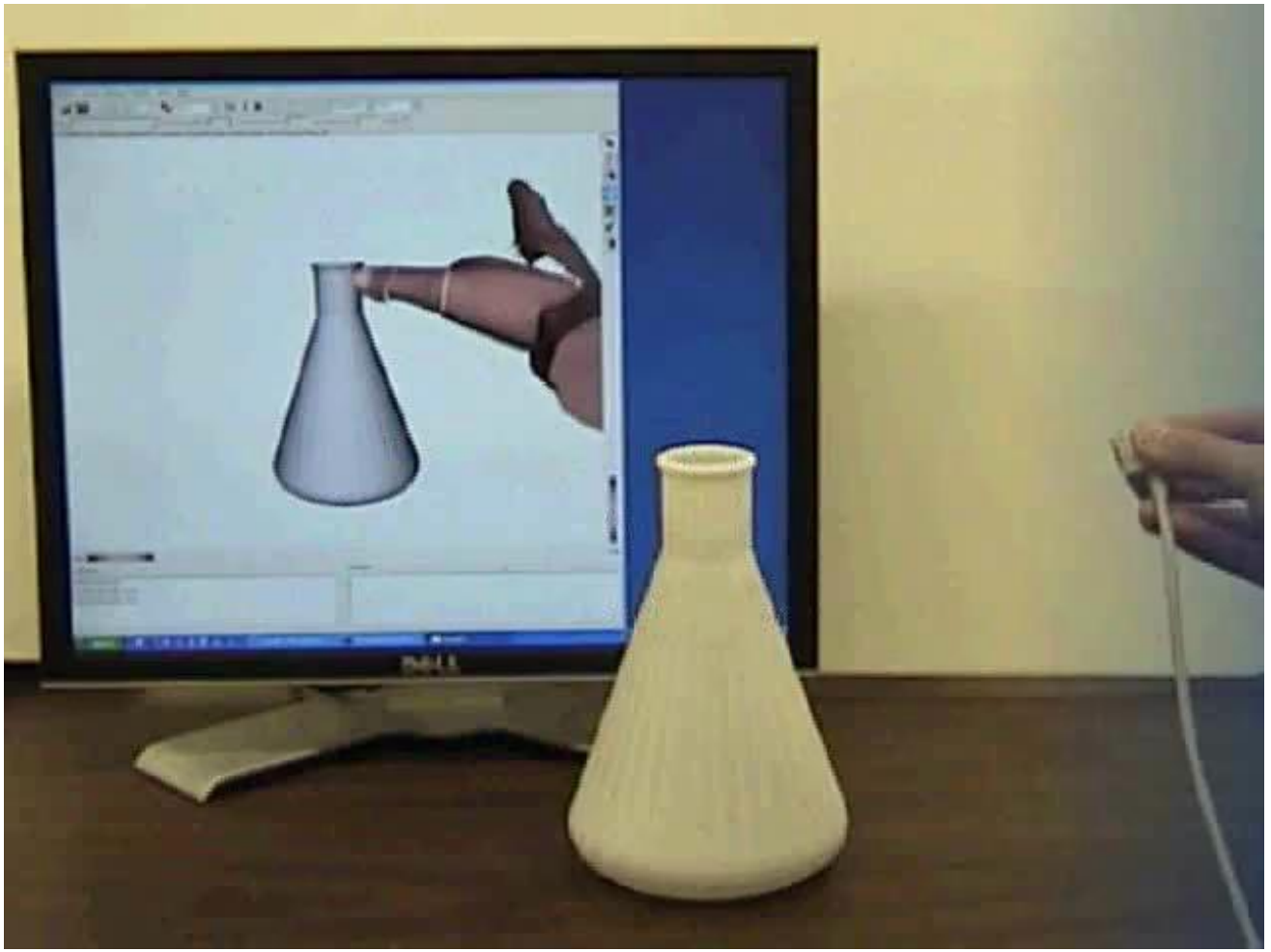




Grasp Planning Using Synergies

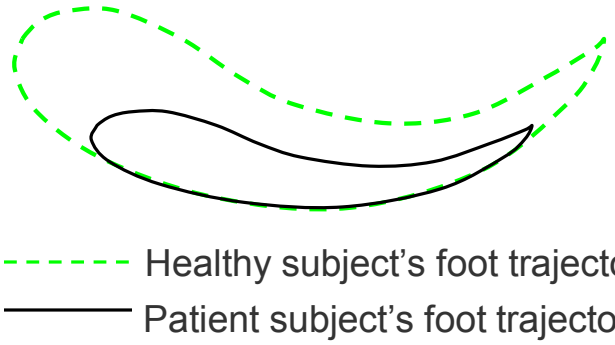
[Ciocarlie et al. 2009]

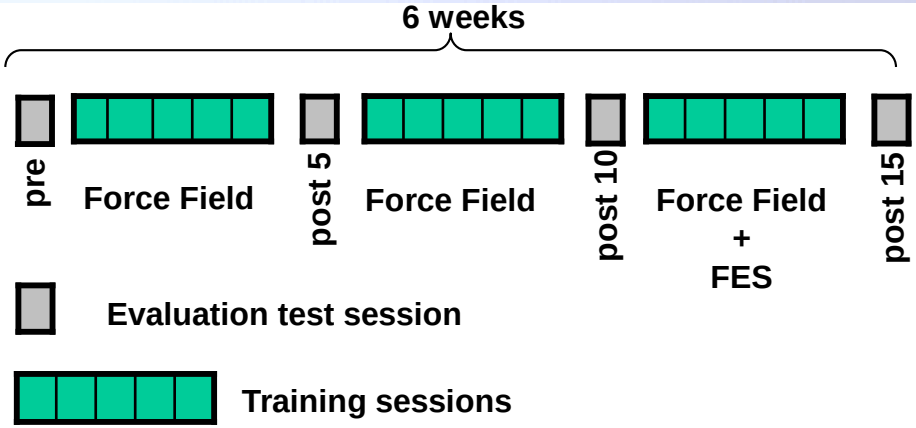
Interactive Grasp Planning



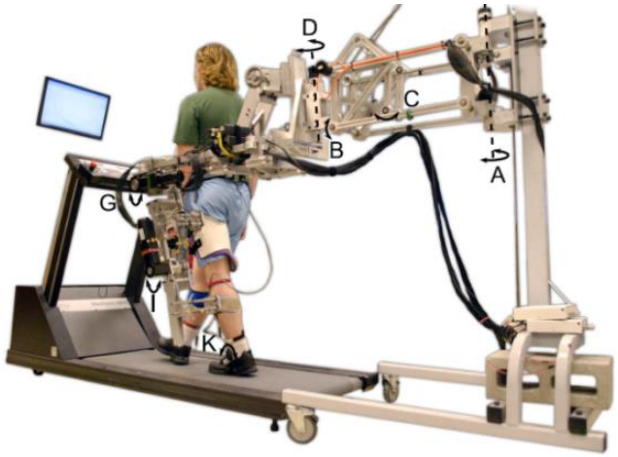
[Ciocarlie et al. 2009]

Chronic stroke patients: Can they learn to walk more normally after robotic training ?





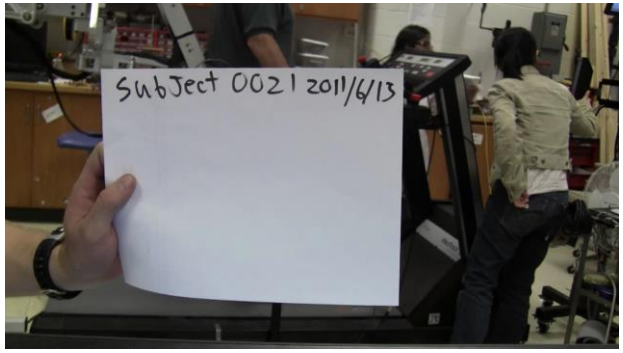
- 3 alternate weeks of training and 6 month follow up
- 5 sessions each week, 40 minutes in each session
- 8 training bouts in a session, gradual force decrease
- Template changed across sessions to match healthy
- N=9

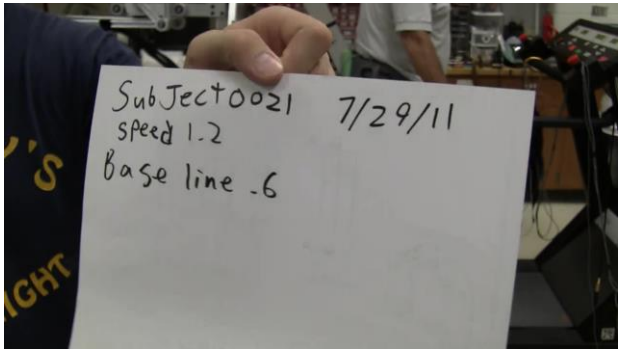


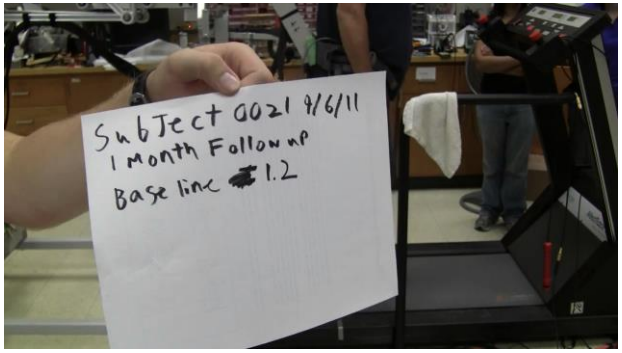
ROBotics And Rehabilitation Laboratory

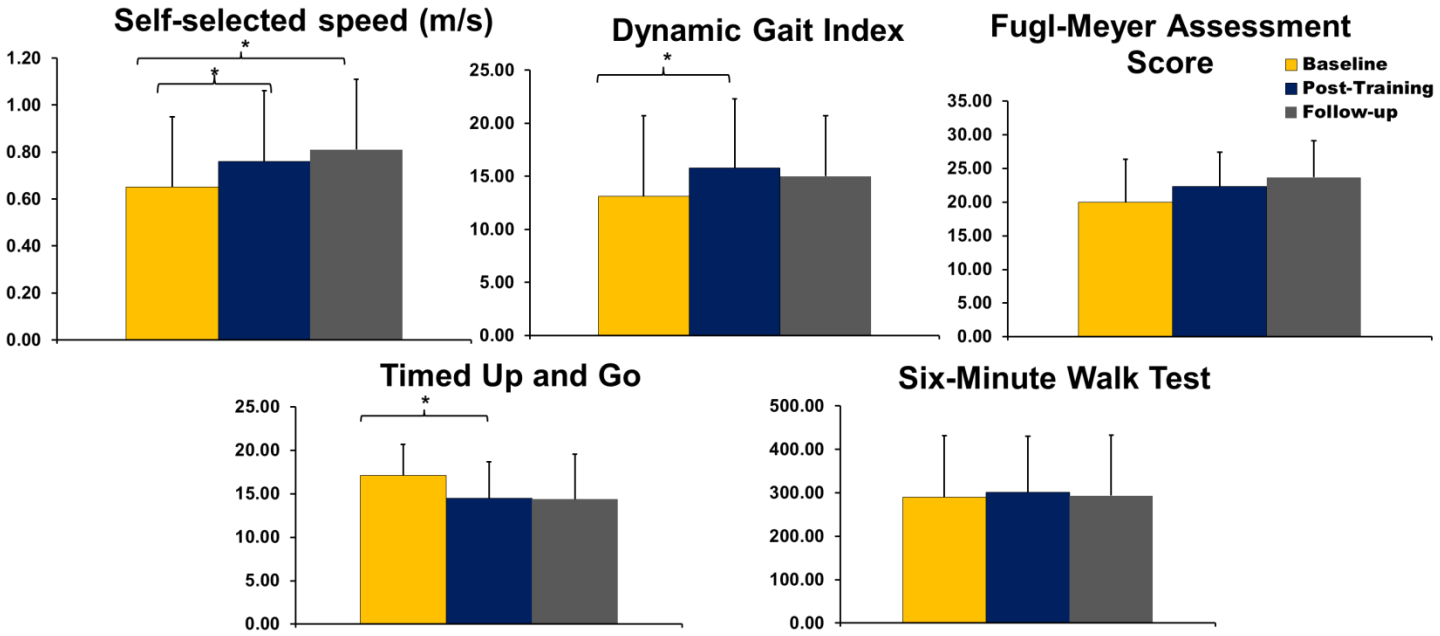
ROBotic Systems Engineering Laboratory

ALEX II – Training results with Stroke Patients









Srivastava, S., Kao, P.C., Kim, S.H., Stegall, P., Zanotto, D., Higginson, J, **Agrawal, S. K**., and Scholz, J. P., "Assist-as-needed Robot-aided Gait Training Improves Walking Function in Individuals Following Stroke", *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 2014.

Brain Science and Robotics

Areas of mutual interest

- Robots controlled by BMI / BCI
- The brain as inspiration for Robotics
- Robotics as inspiration for understanding the brain
- Rehabilitation robotics and motor learning
- …

Fostering collaboration (from the IEEE RAS):

- RAS encourages joint technical committees
- Must increase interest in papers in Brain science that relate to RAS
  - Often they do not contain enough robotic innovation
- Renew interest in robotic research by joining the IEEE Brain Initiative