AI

IA

IA

(Intelligence Amplification)

I get ~~by~~ AI with a little help from my ~~friends~~ friend's brains

John Lennon

Smarter Parts: Intelligence, Learning, and Communication in Human-Prosthesis Interaction

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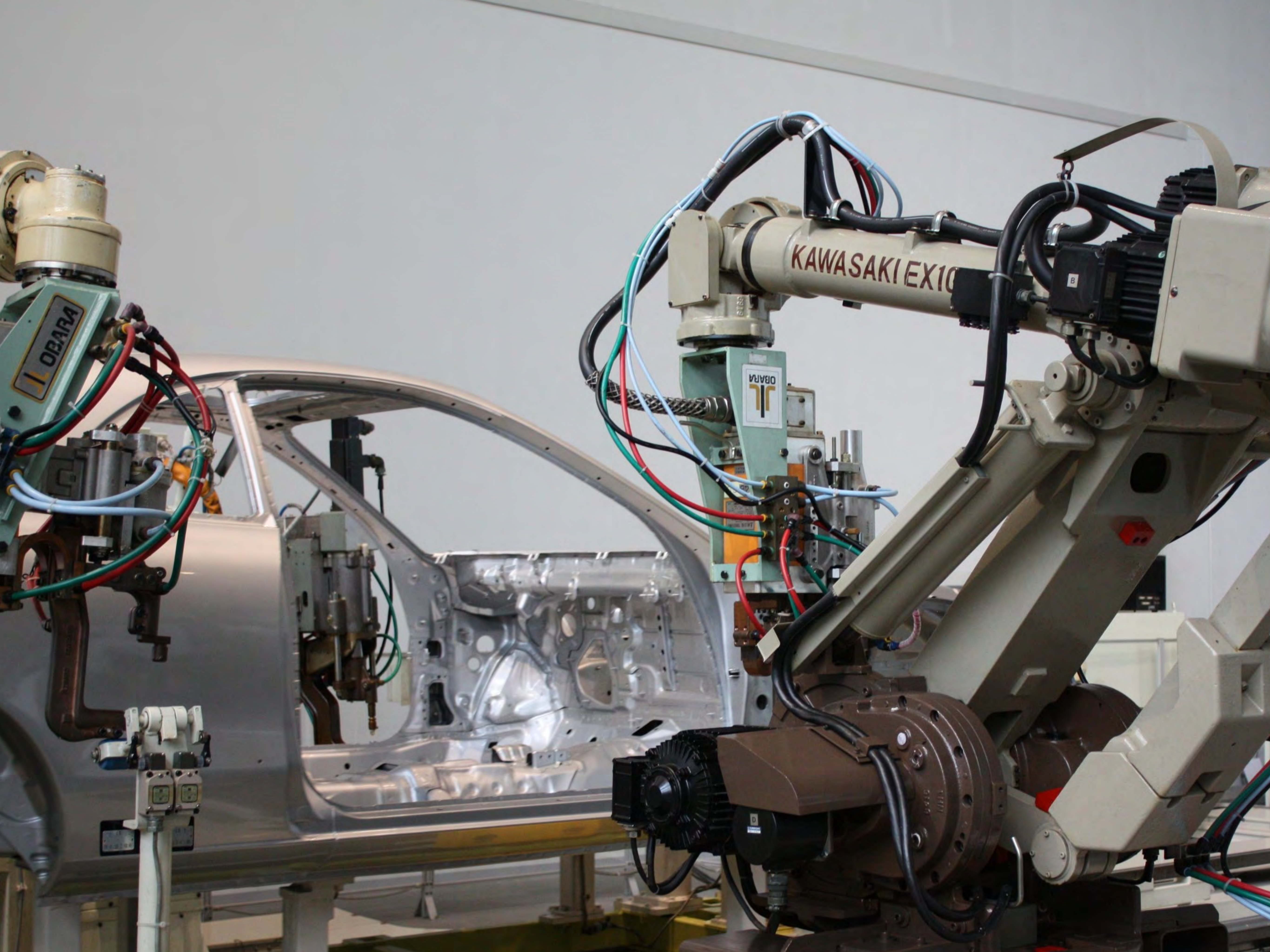
UNIVERSITY OF ALBERTA

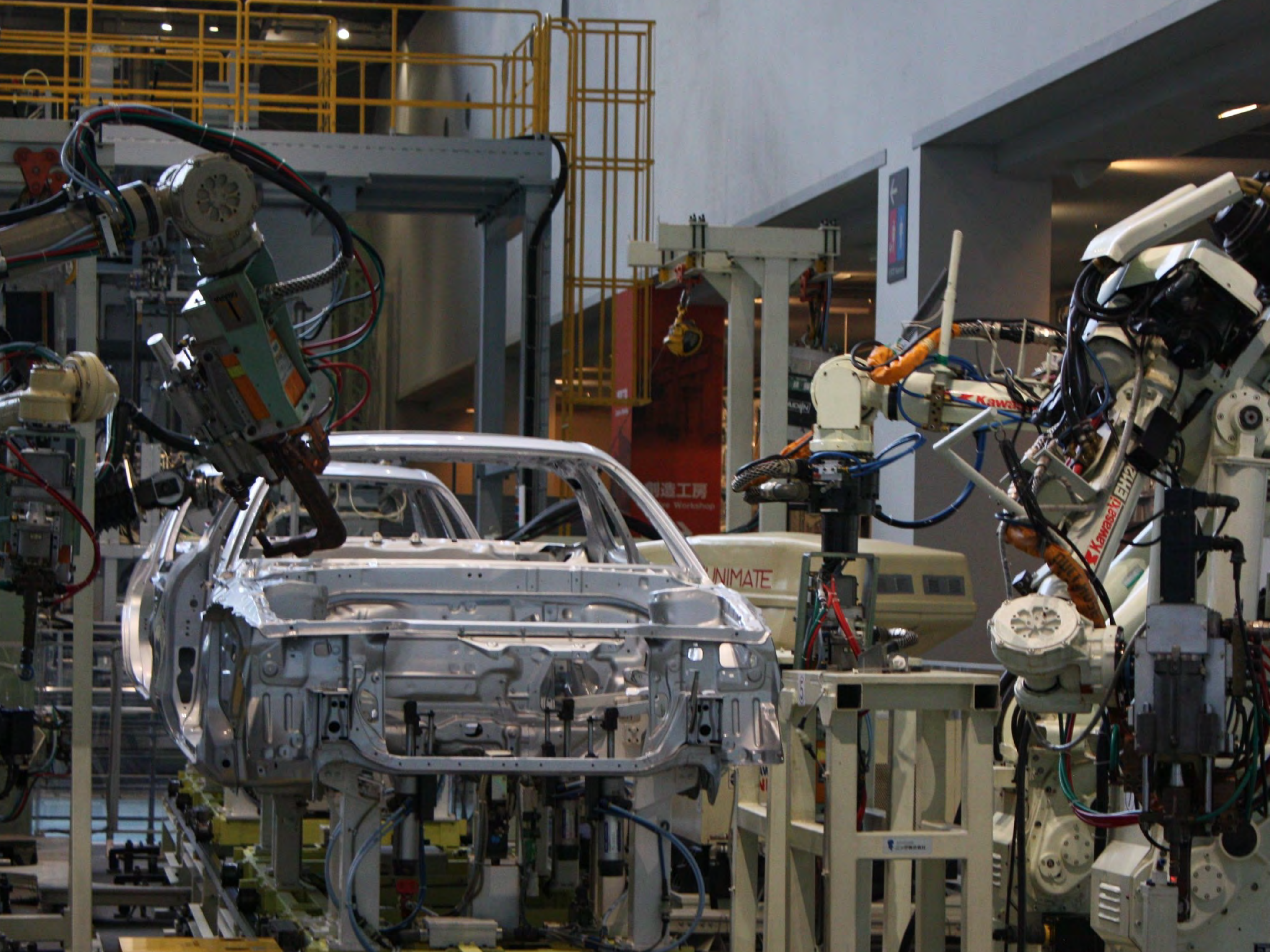
EDMONTON·ALBERTA·CANADA

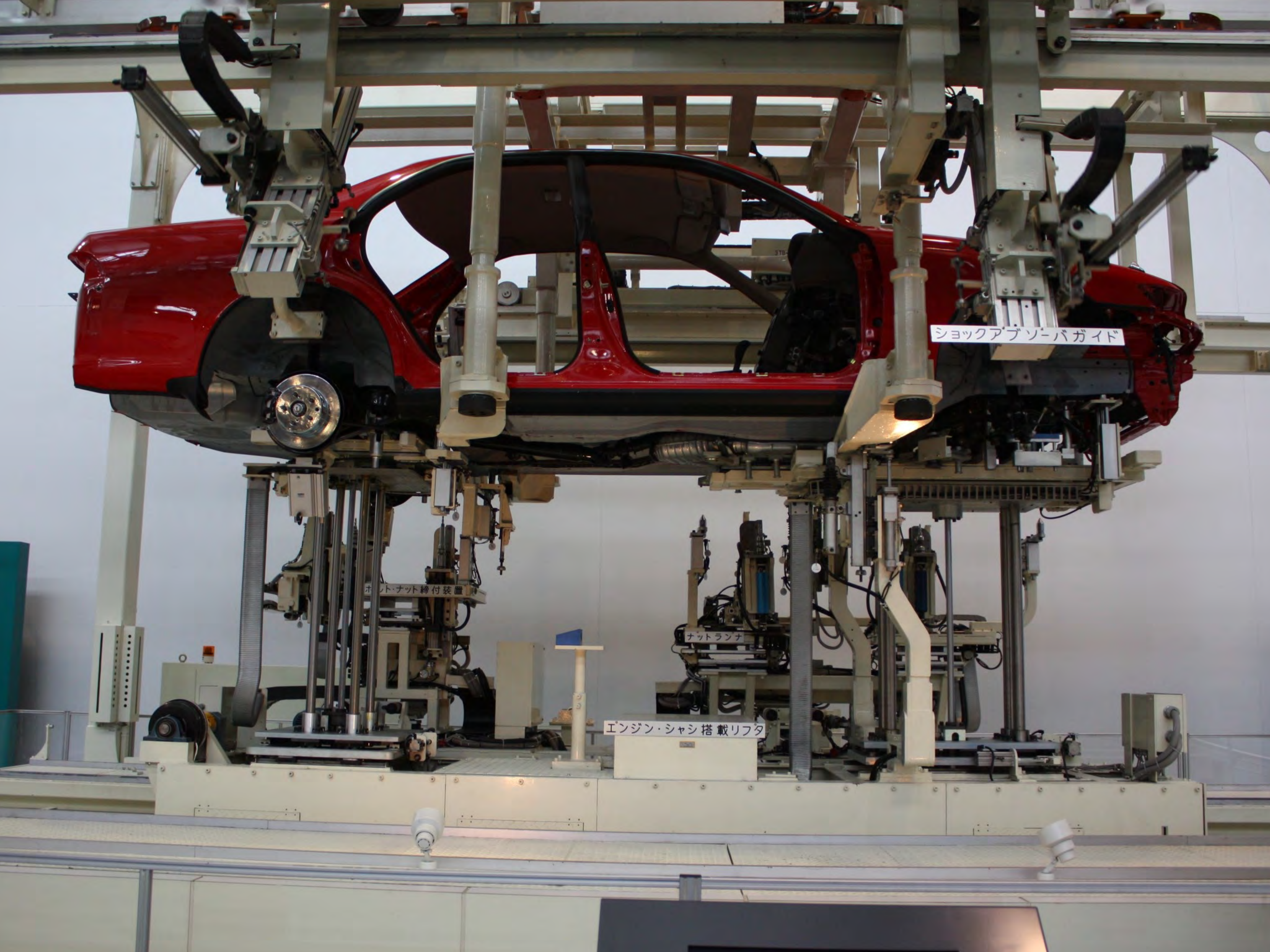
STICK
{a stick,
branch,
twig}

{force multiplier,
remote actuation}

STICK
{a stick,
branch,
twig}


KAWASAKI EX10
OBARA
OBARA


UNIMATE
Kawasaki

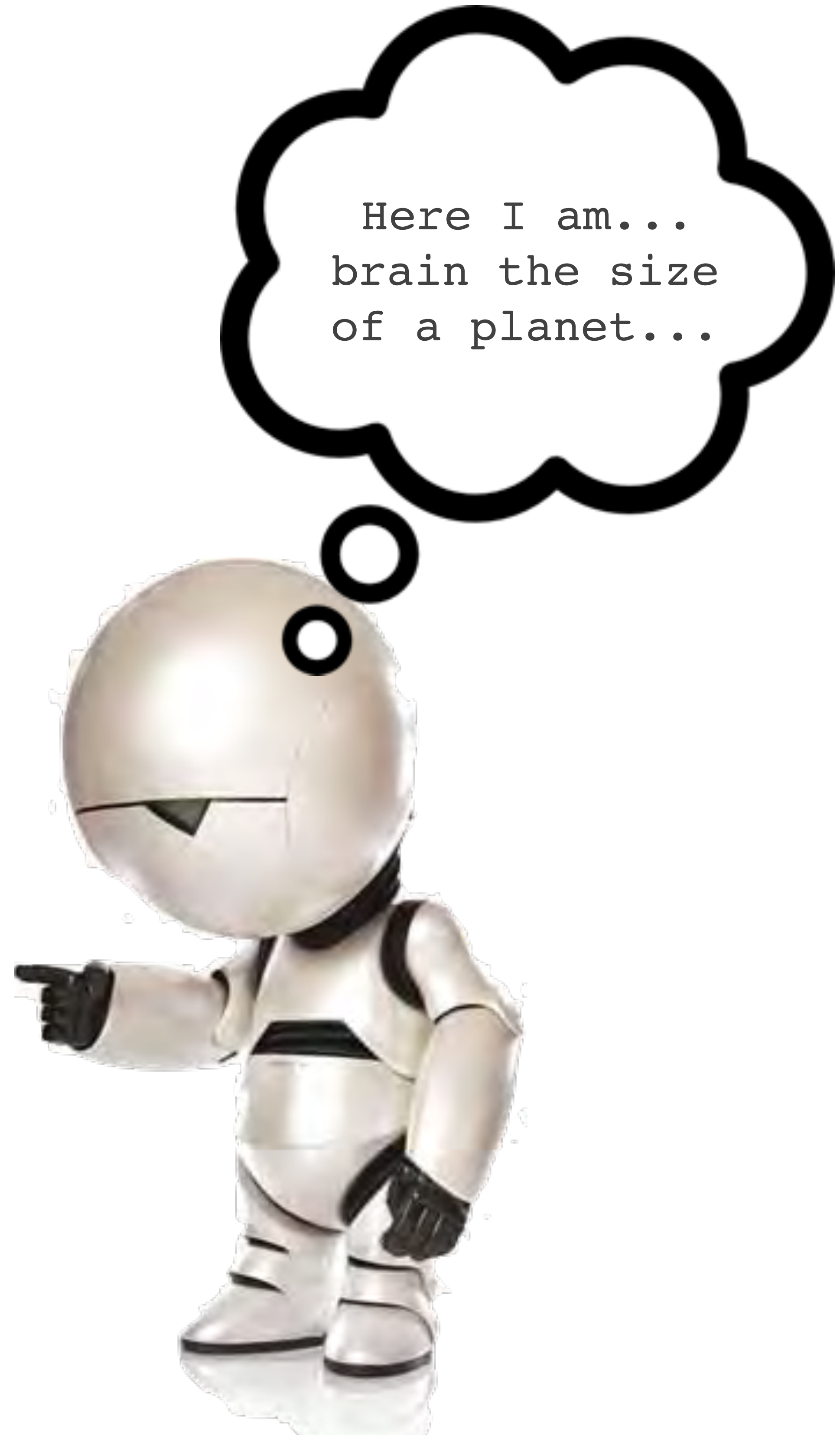

ショックアブソーバガイド
ト・ナット締付装置
ナットランナ
エンジン・シャシ搭載リフタ

SPINNING WHEEL

{animal fur,
plant matter}
>>
{thread,
yarn}


muratec

… and, in short order …



Marvin the paranoid android from THHGTTG.

Machines learn and adapt to human users . . .

…humans change to better interact with machines.

Towards Super-human Intelligence

Stairwell from
Antoni Gaudi's La Sagrada Familia

Brain-Body-Machine Interfaces (BMIs)

two systems working together in partnership to achieve shared objectives.

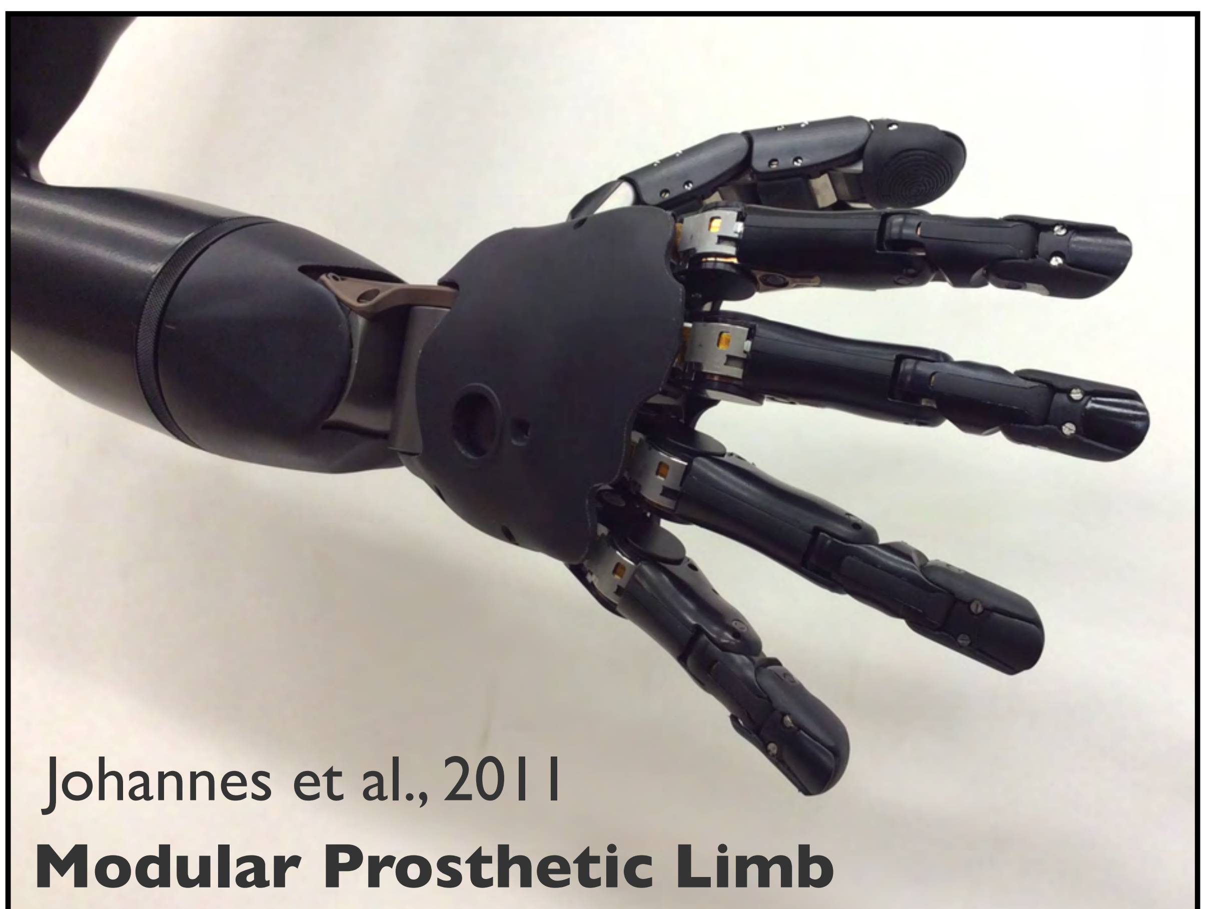
in most rehabilitation settings, one system **directs** (human), the other **assists** (machine).


Outside. Pee outside.
Seriously: pee outside!
Whee! I can pee
on carpets!

Upper-limb Prosthetics

(from cables-and-hooks to bionic bodies)

Advanced bionic technology exists …

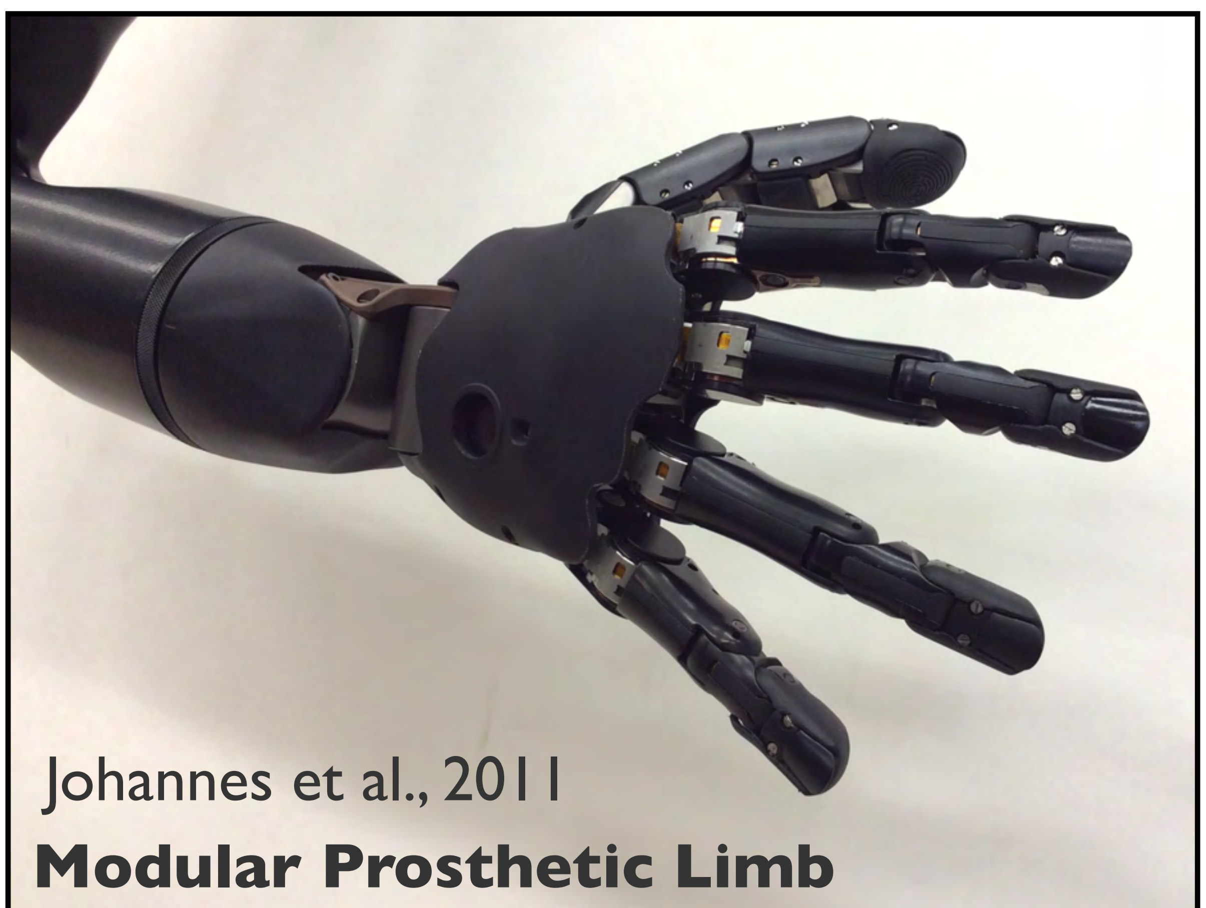


... but there are barriers to using it.

Function
Control
Feedback

(Peerdeman 2011, Scheme 2011, Micera 2010, Resnik 2012)

Advanced bionic technology exists …



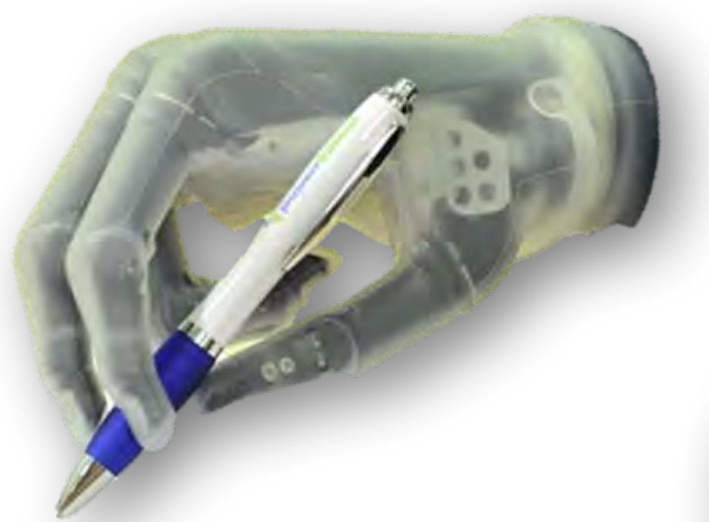

Courtesy of DEKA Research & Development and
The Rehabilitation Institute of Chicago

Direct brain-computer interfaces: study participant Jan Scheuermann feeding herself with a robotic limb (University of Pittsburgh)
http://www.upmc.com/media/media-kit/bci/Pages/default.aspx

Hybrid Assistive Limb (HAL): Cyberdyne Inc., Japan.

Rehabilitation Institute of Chicago (RIC) research subject, **Zac Vawter** at the top of the Willis Tower in Chicago (Photo: The Associated Press).

Principal Challenge for the Control of Neuroprostheses



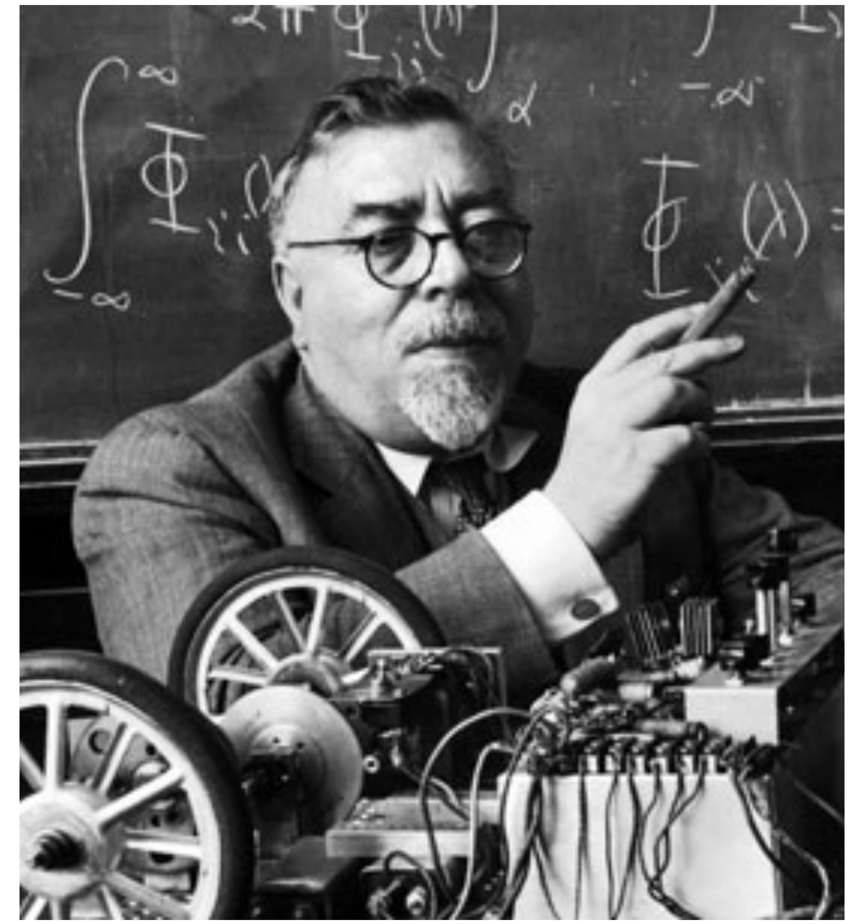
- Increasing number of functions or actuator configurations that a user can select/control.
- The controllable functions typically outnumber the available control channels

Castellini et al, 2014; Scheme and Engelhart, 2011; and others.

- Future assistive devices will receive an unprecedented density of data about a user, their needs, and their environment.

- This stream of data will need to be skillfully leveraged to enable the coordination of vast numbers of actuators and functions.

- Prostheses are beginning to take an **active role** in this process.



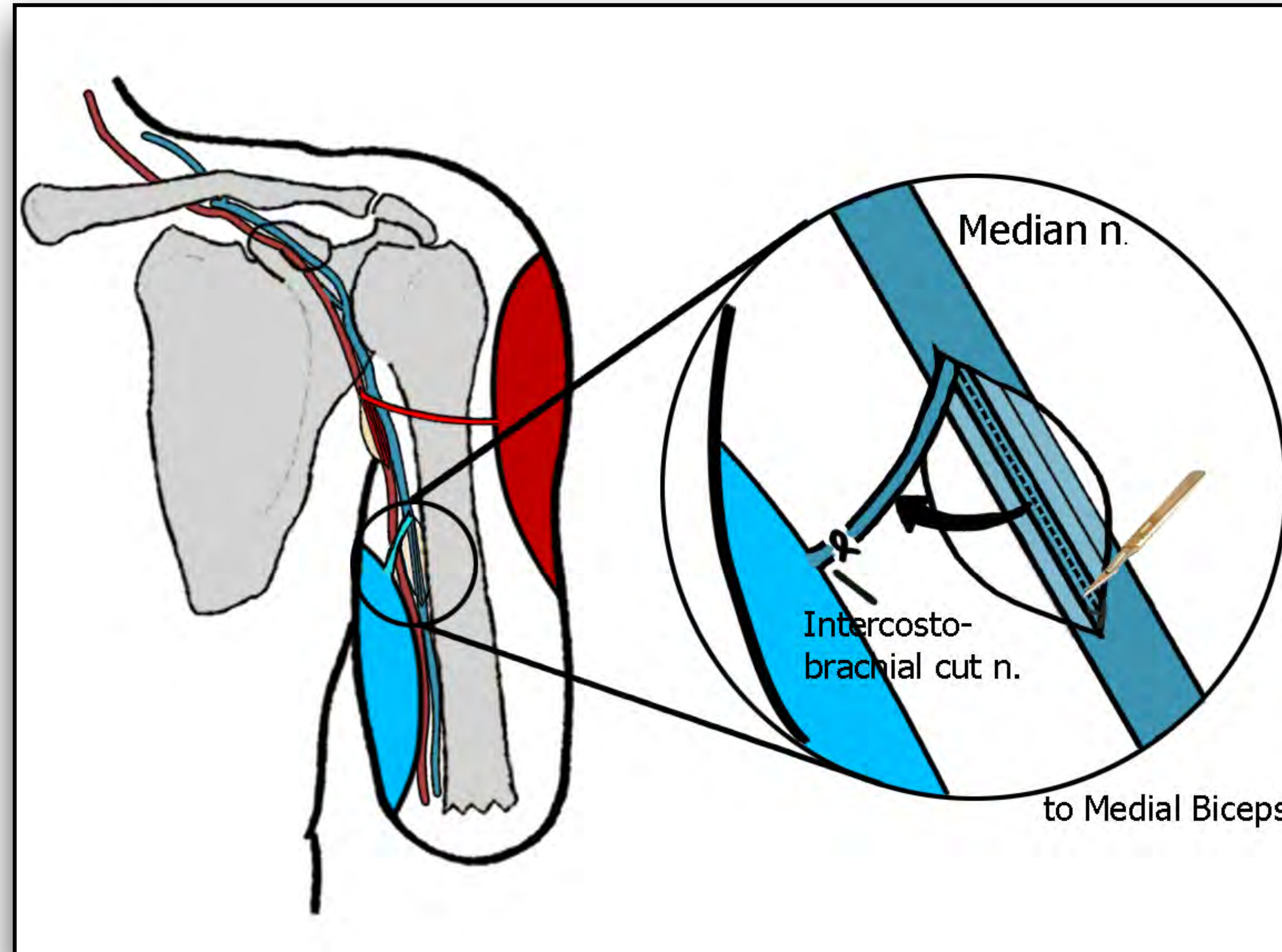
c.f., **Norbert Wiener**, 1948: *Cybernetics: Or Control and Communication in the Animal and the Machine.*

… Mechanisms …

evaluating and improving
conventional prosthesis control
(both human and machine elements)

Sequential (Switched) Myoelectric Control

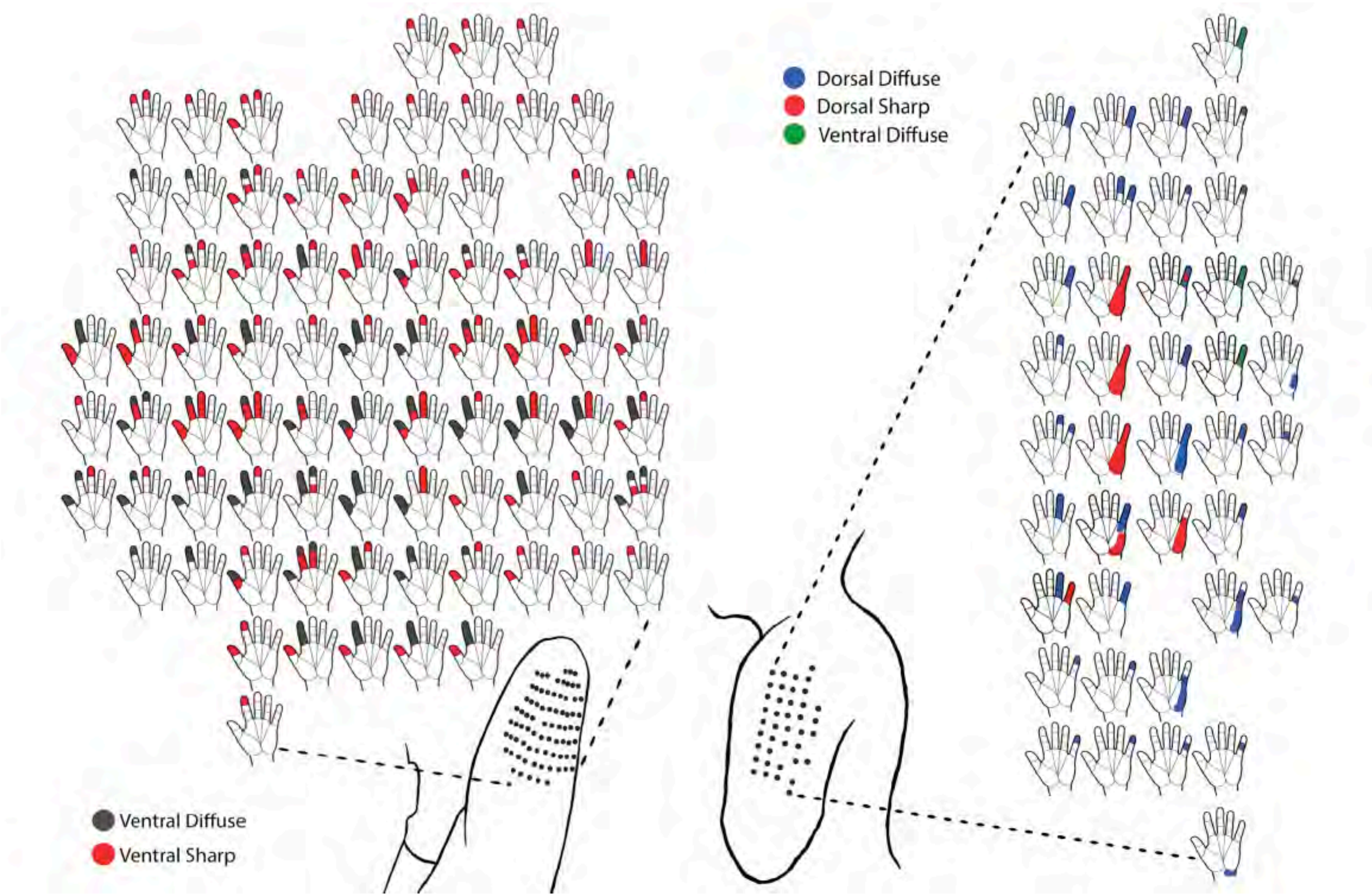
Re-wiring the Nerves



TSR: Targeted Sensory Reinnervation

Hebert et al. 2014, IEEE-TNSRE

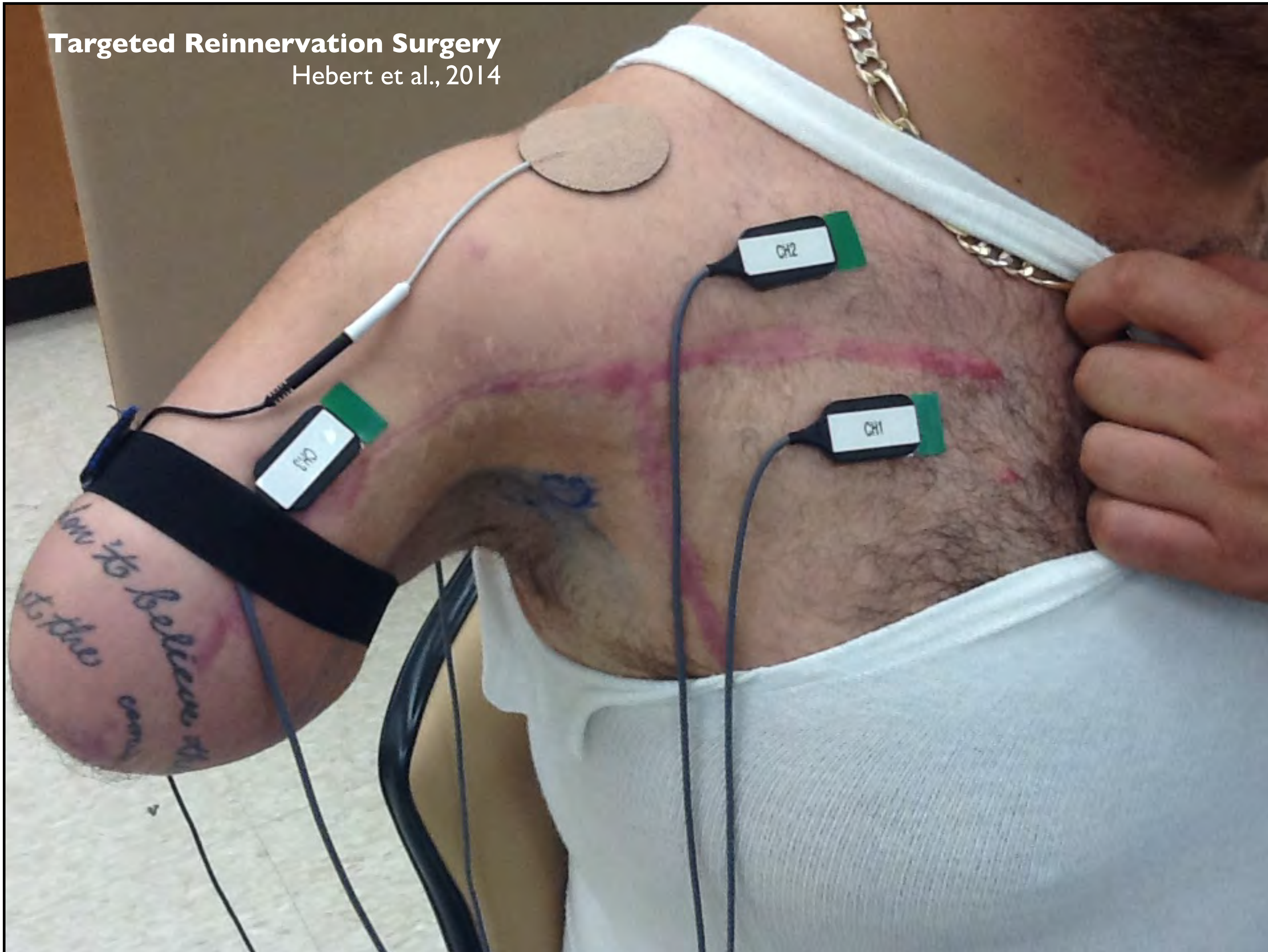
Re-wiring the Nerves



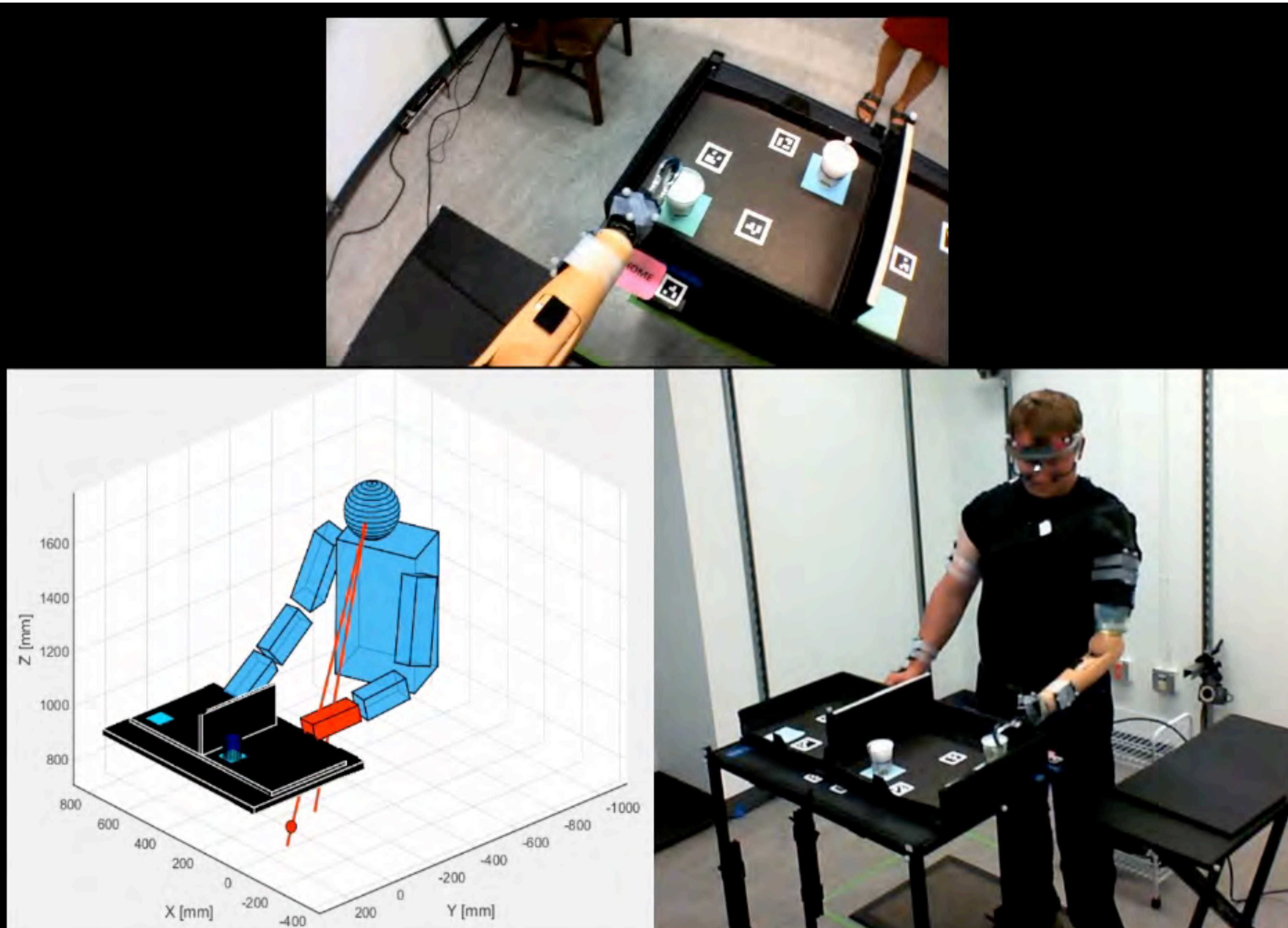
TSR: Targeted Sensory Reinnervation
Hebert et al., 2014, IEEE-TNSRE

Targeted Reinnervation Surgery

Hebert et al., 2014



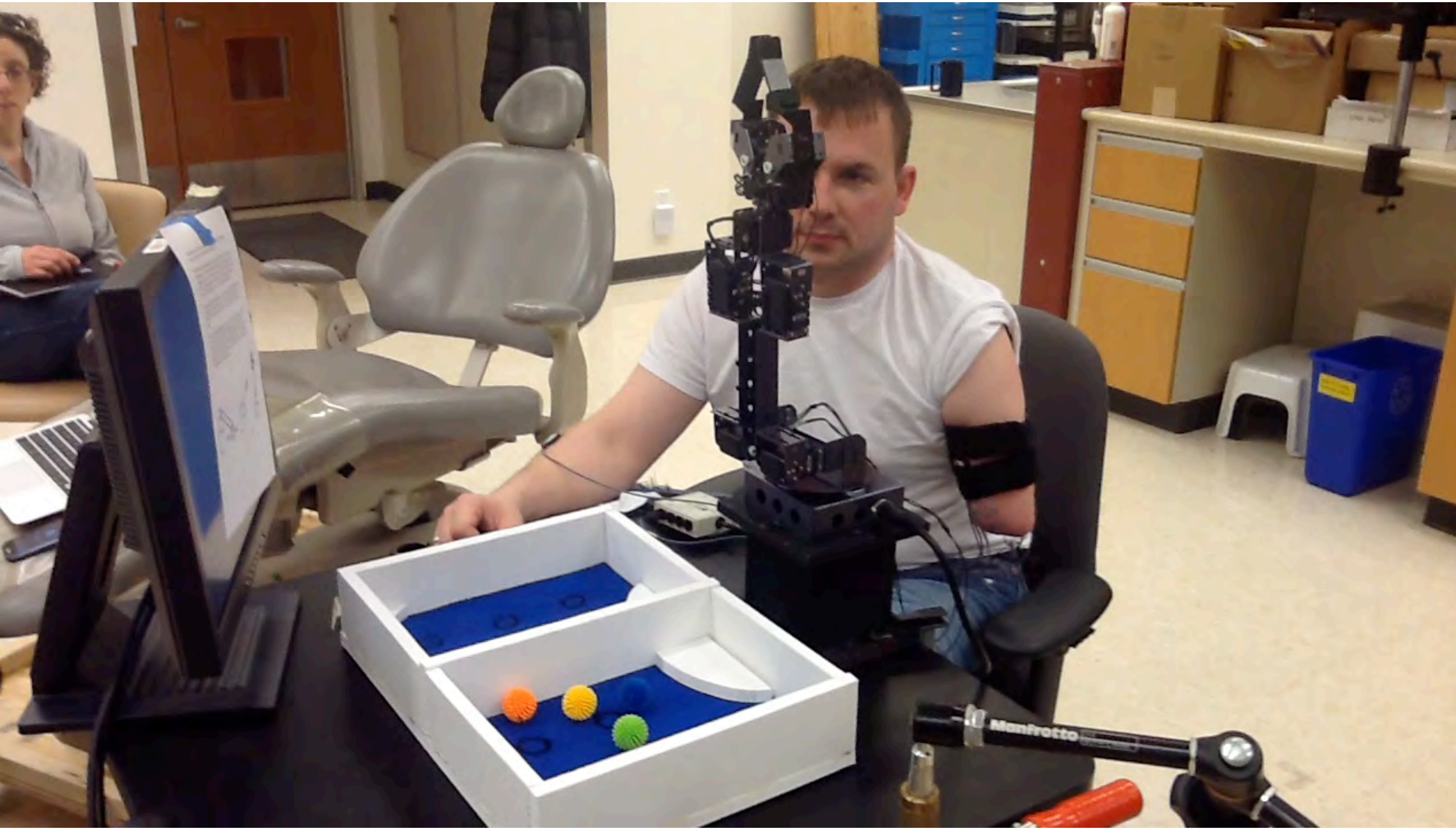
DARPA HAPTIX Measures: Prosthetic User



… Machine Learning …

enhancing prostheses with
machine prediction and control learning

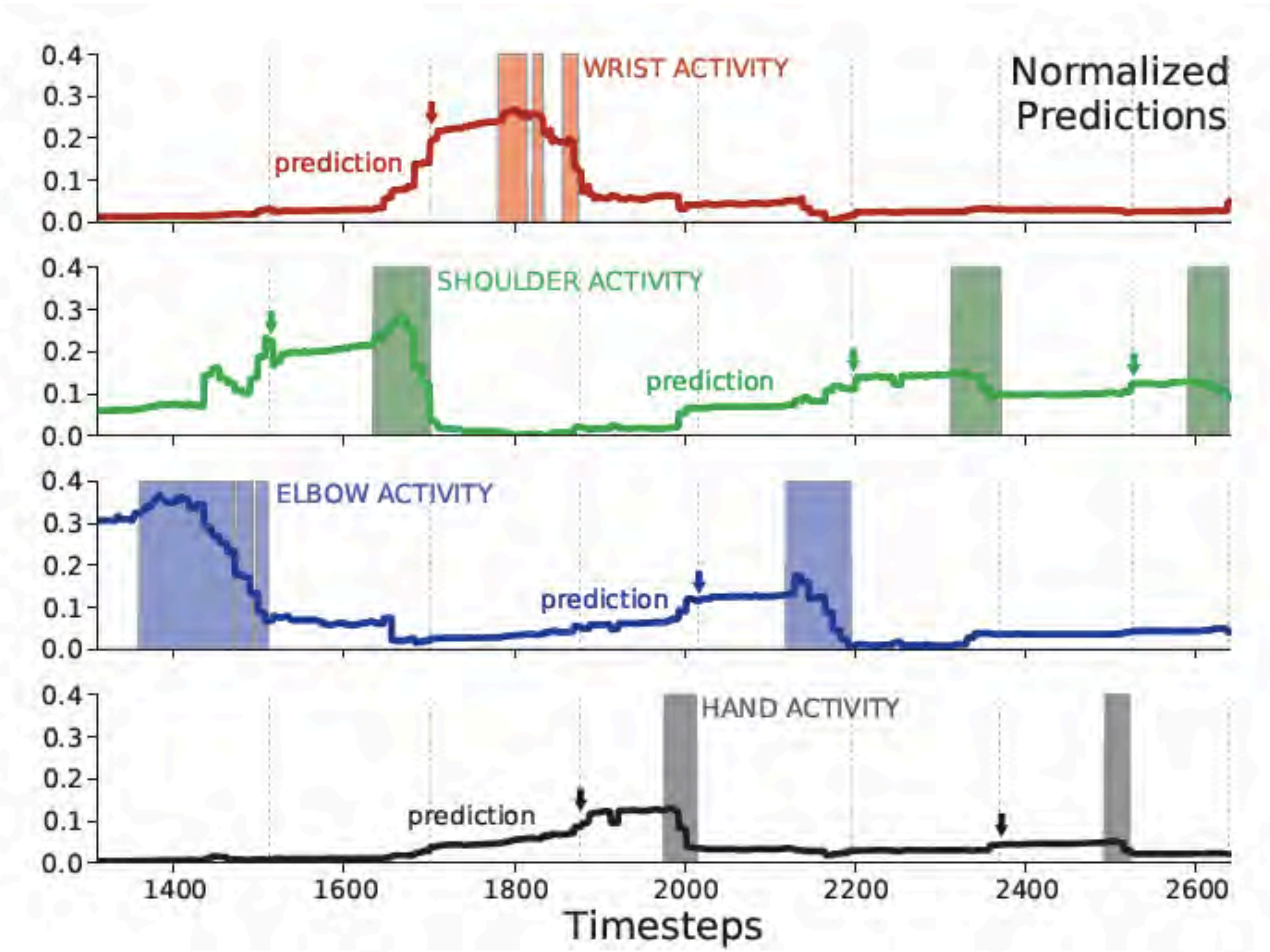
Commercially Deployed
Pattern Recognition



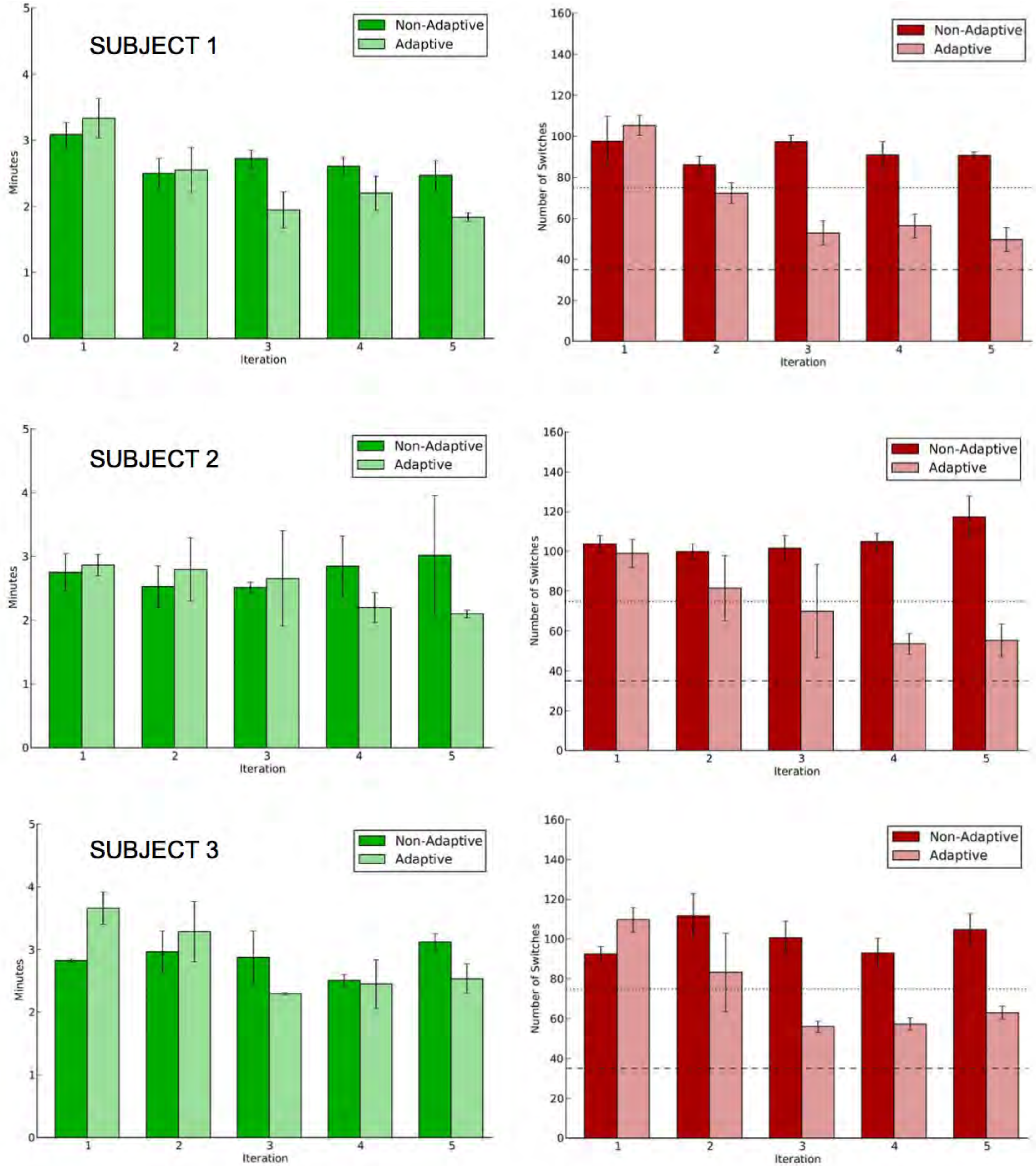
Adaptive Switching

Edwards et al., *MEC*, 2014
Edwards et al., *Prosthetics Orthotics Int.*, 2015

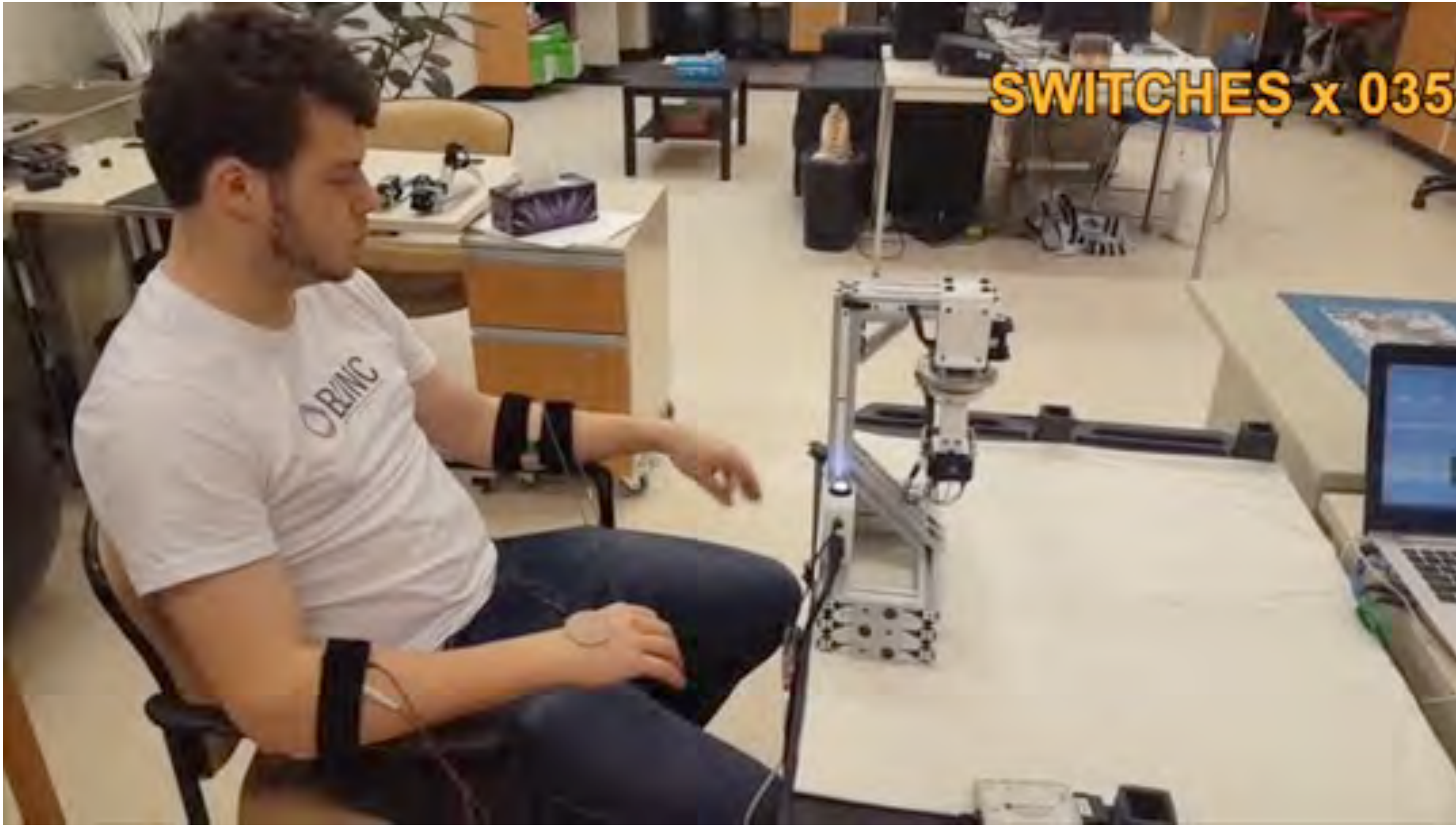
Predicting the Future



Pilarski et al., 2012, BioRob



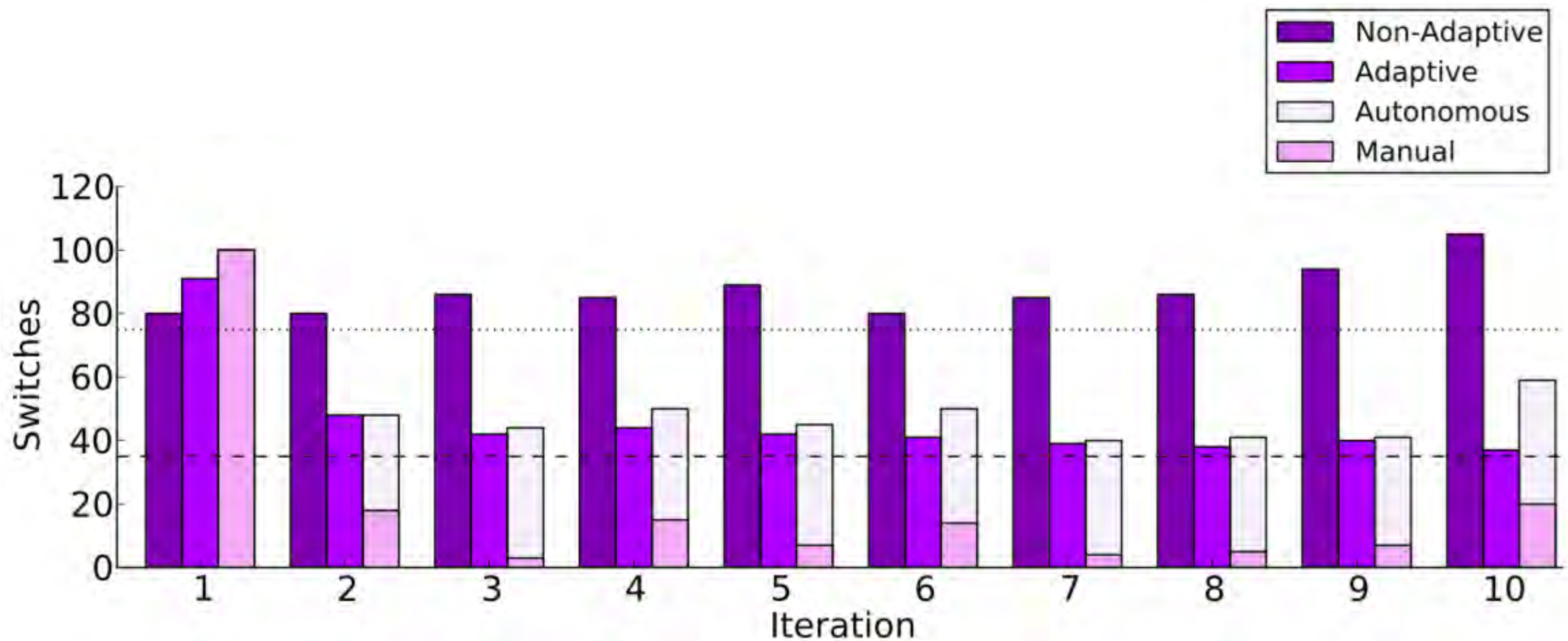
Edwards et al., *Prosthetics Orthotics Int.*, 2015

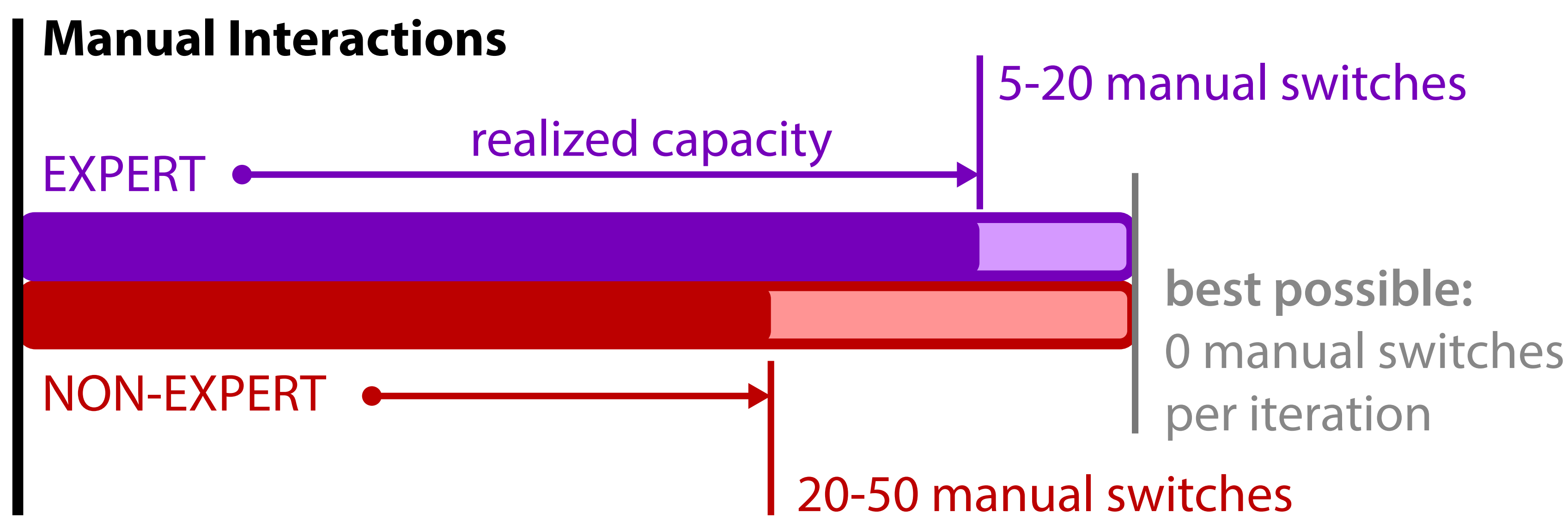


Autonomous Switching

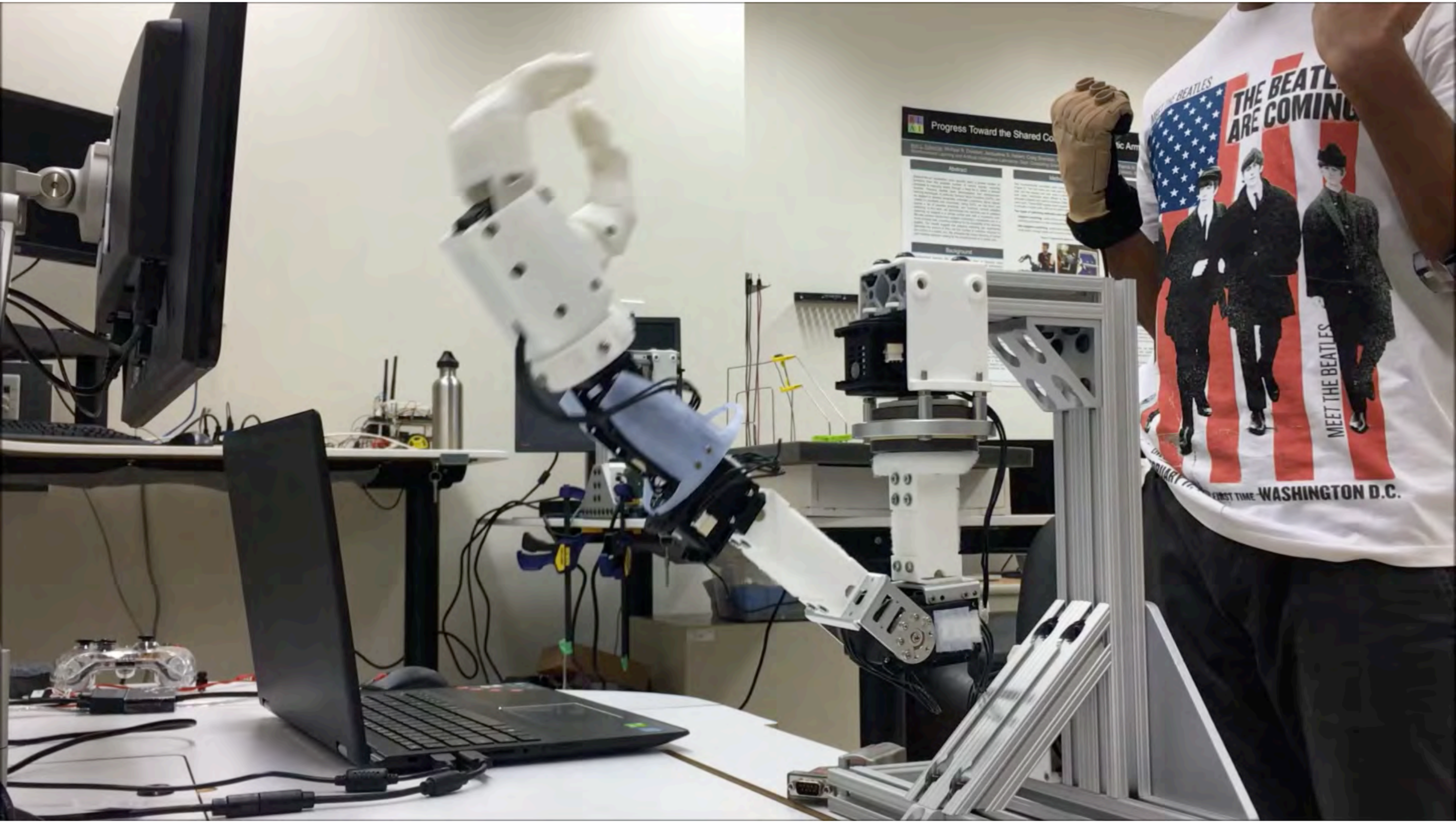
Edwards et al., *BioRob*, 2016

(learning and unlearning automatic control actions)





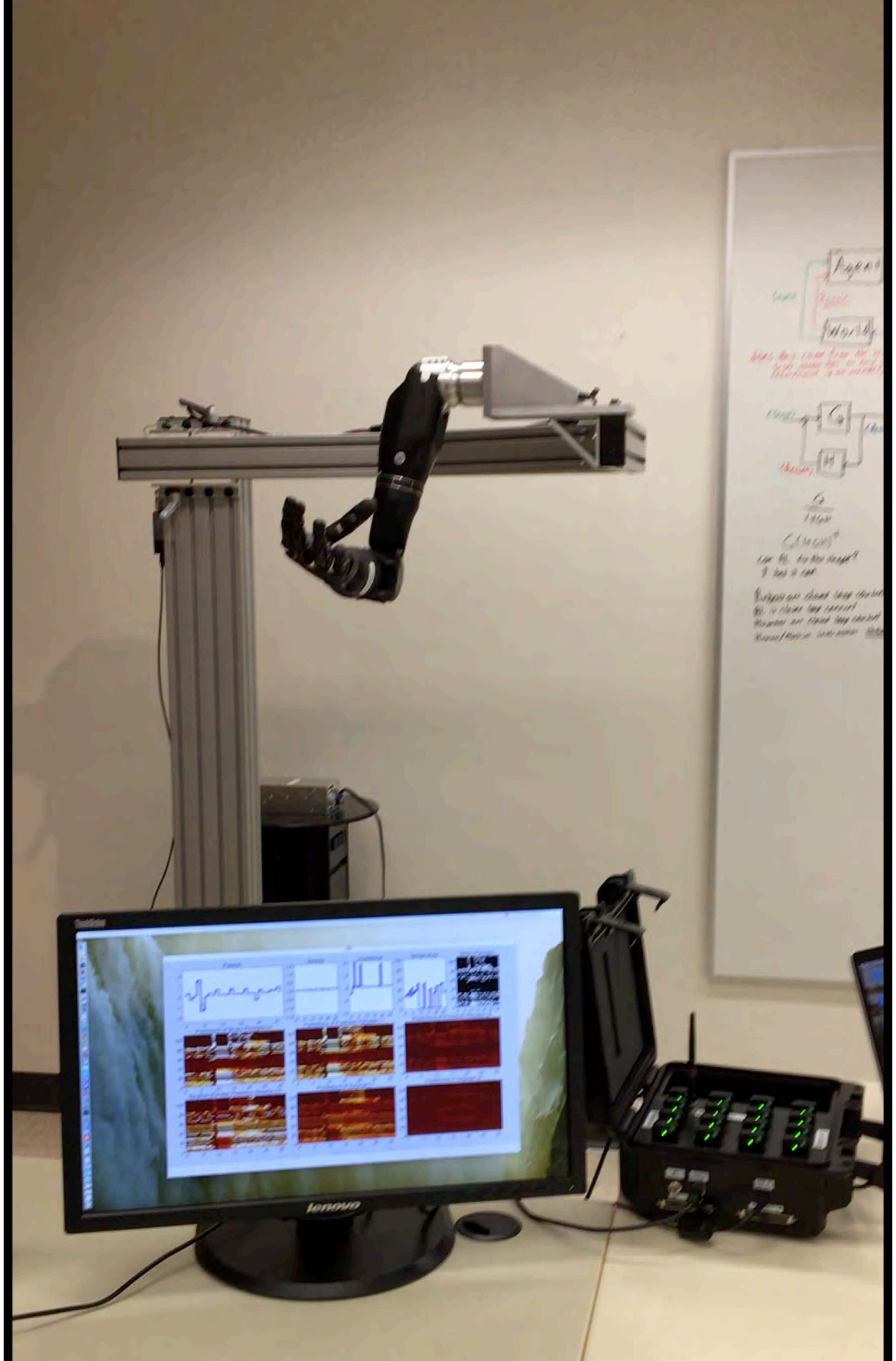
Pilarski et al., arXiv *2017;* Edwards (2016) *M.Sc. Thesis*



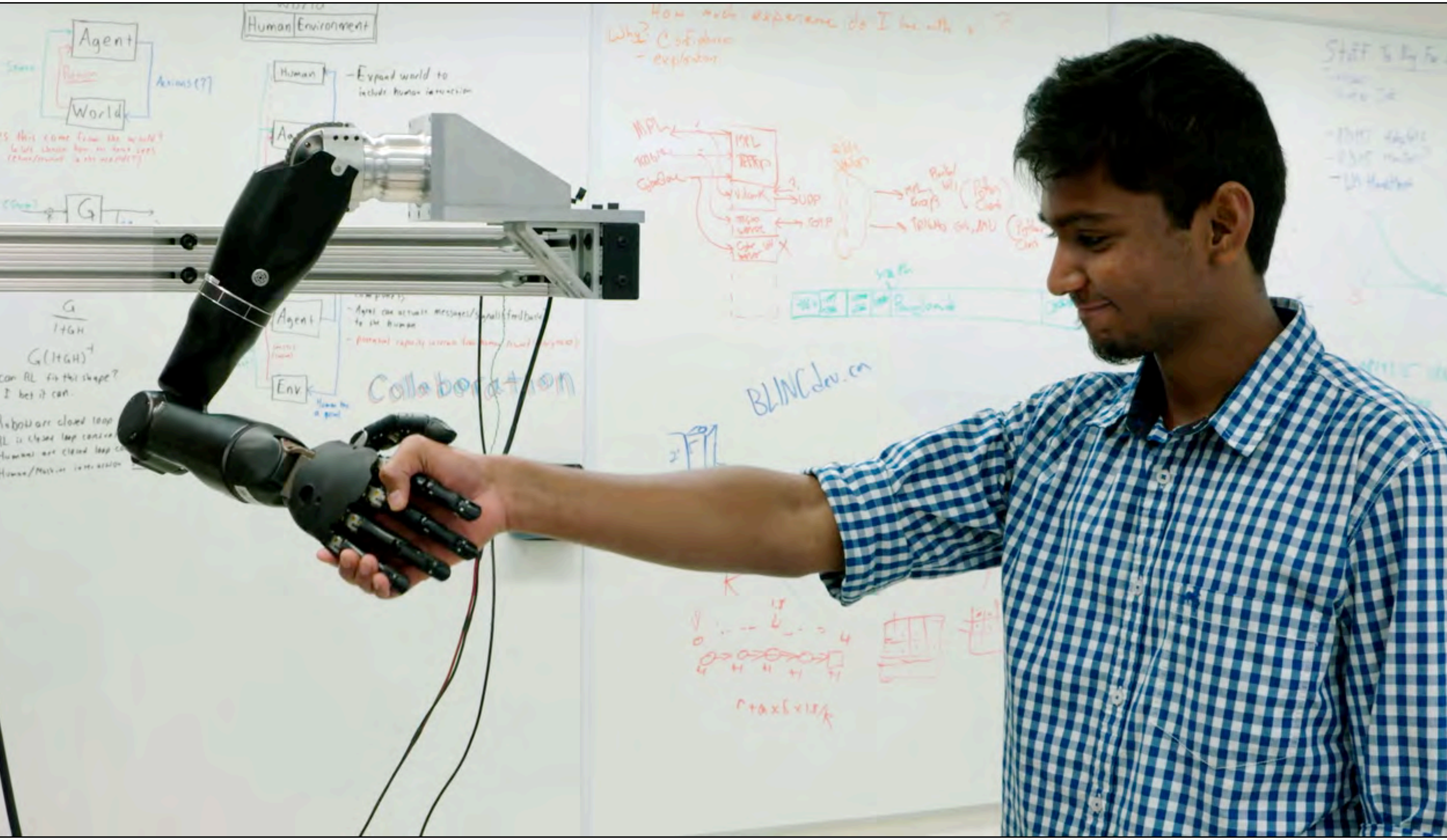
Vasan, *M.Sc. Thesis*, 2017; Vasan et al., *ICORR*, 2017

Towards Smarter Parts

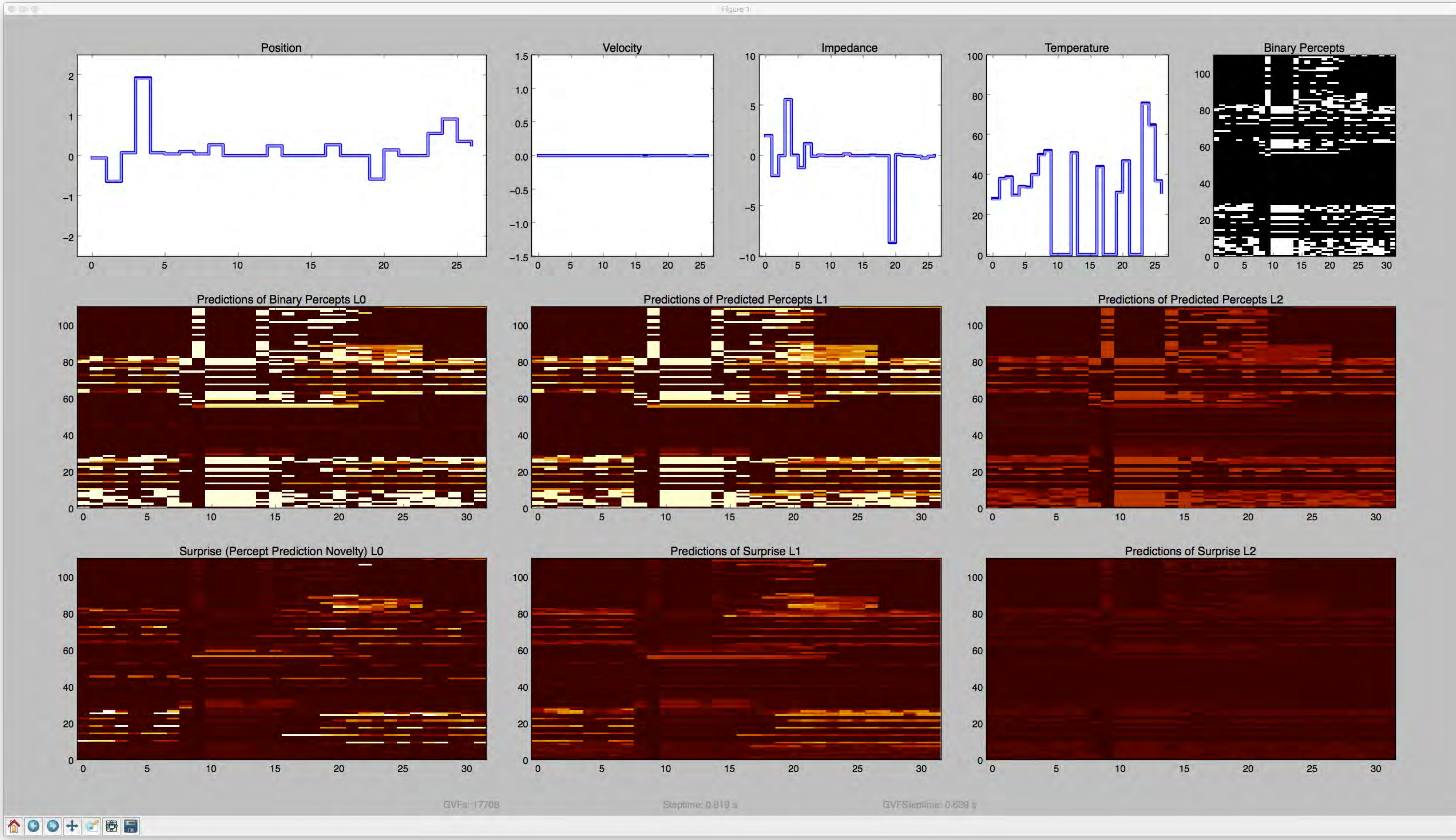
moving beyond engineered solutions
and towards more general prosthetic intelligence



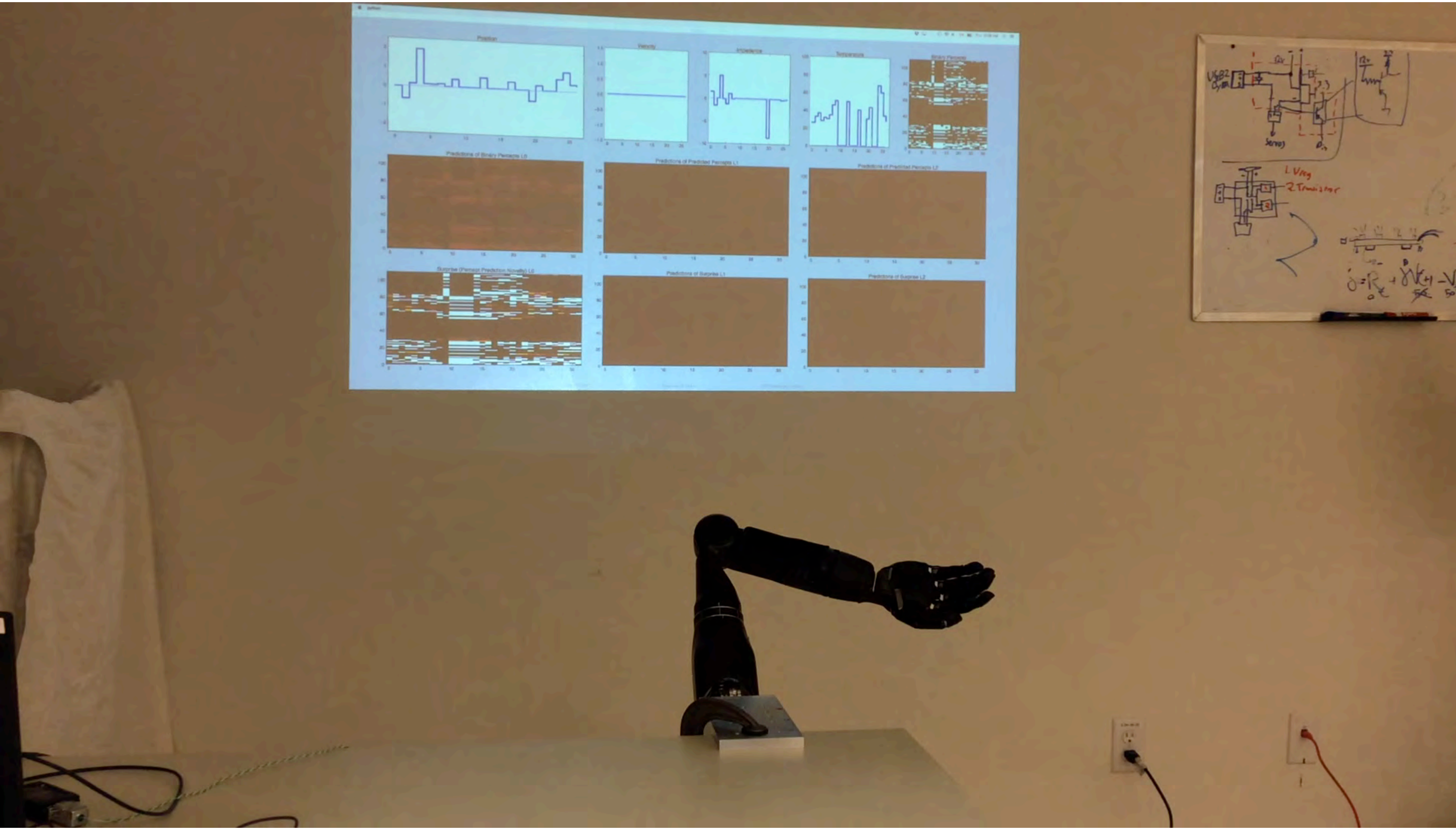
Pilarski Lab
Jan. 2017



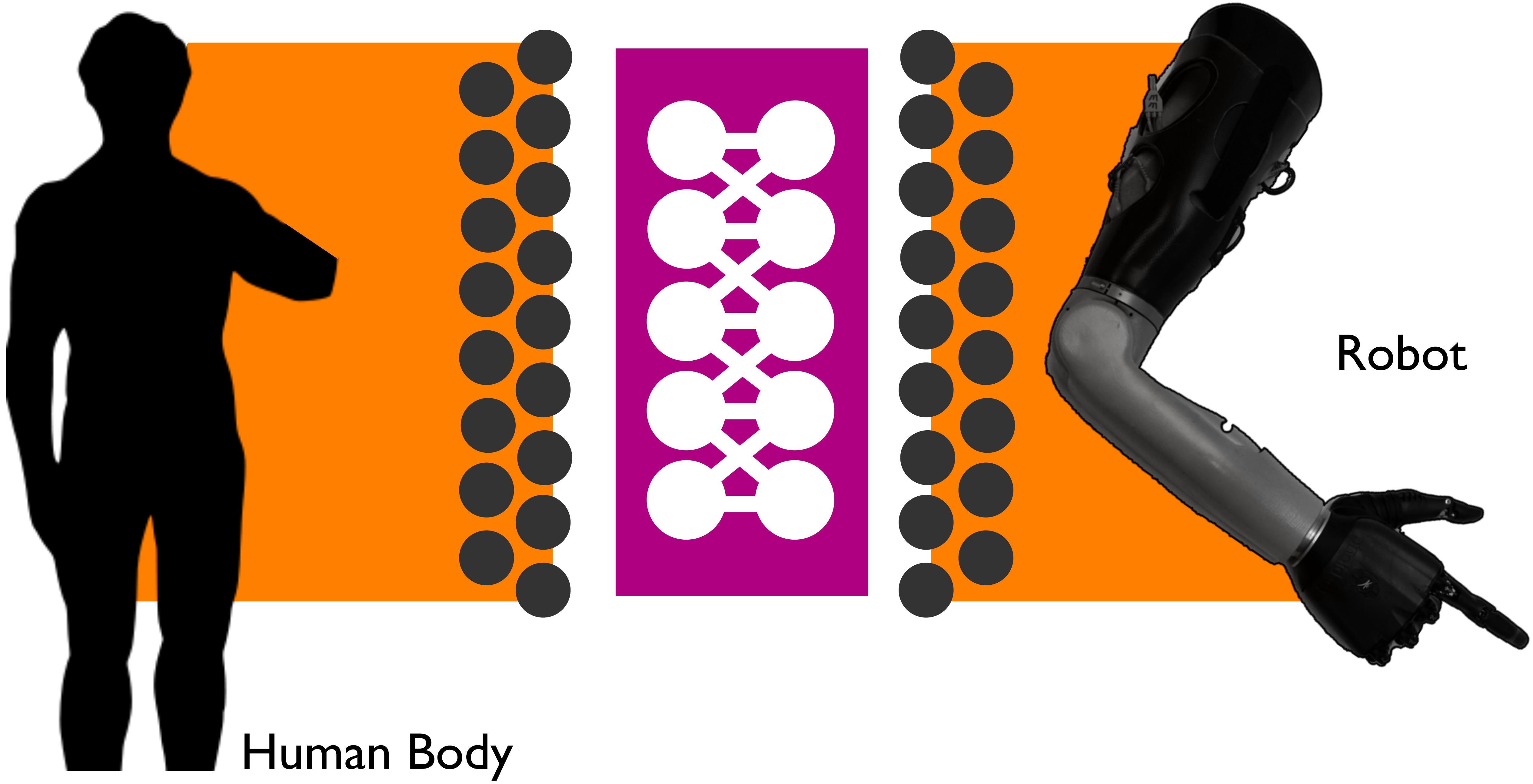
Pilarski Lab
August 2016

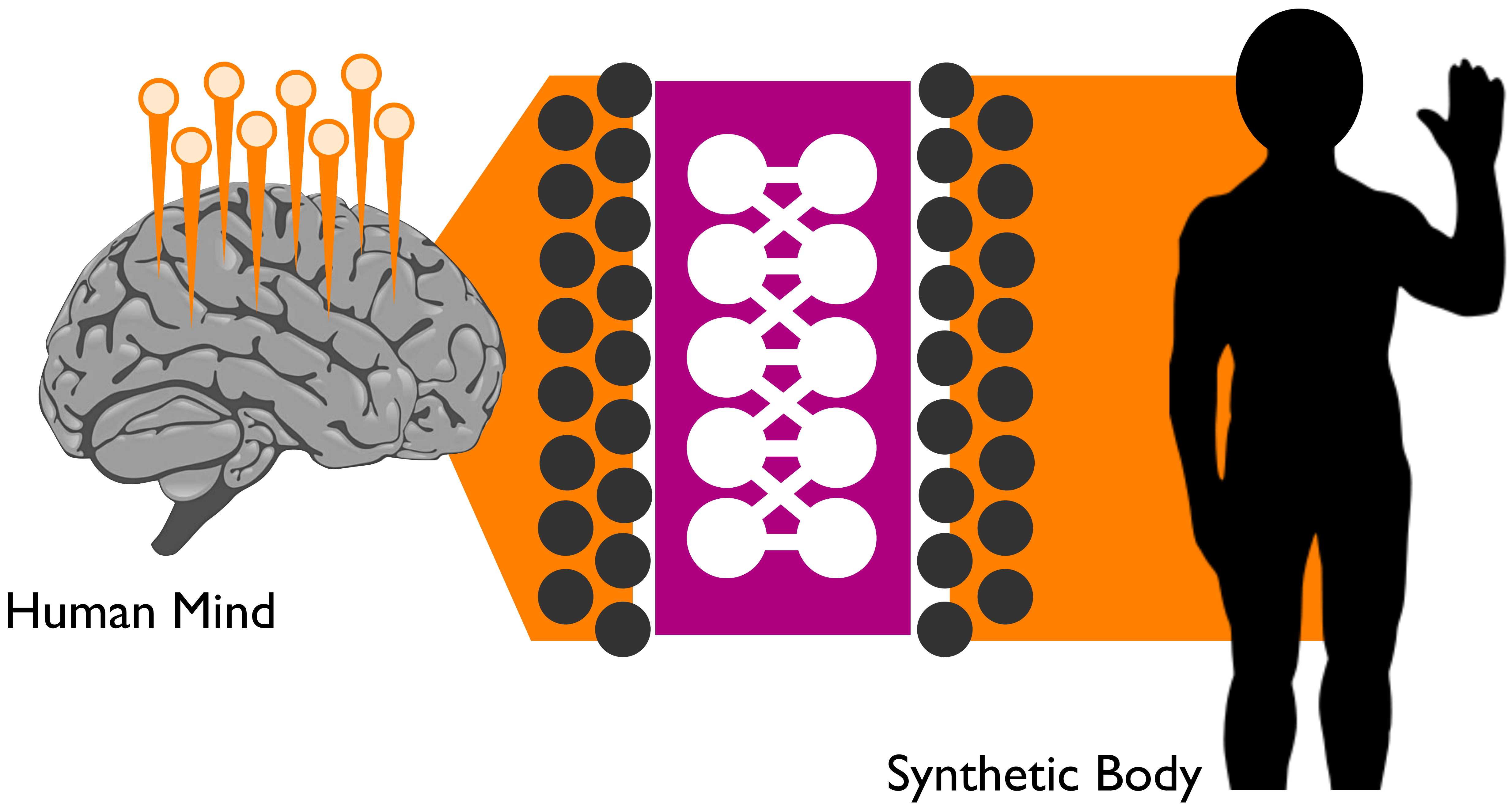


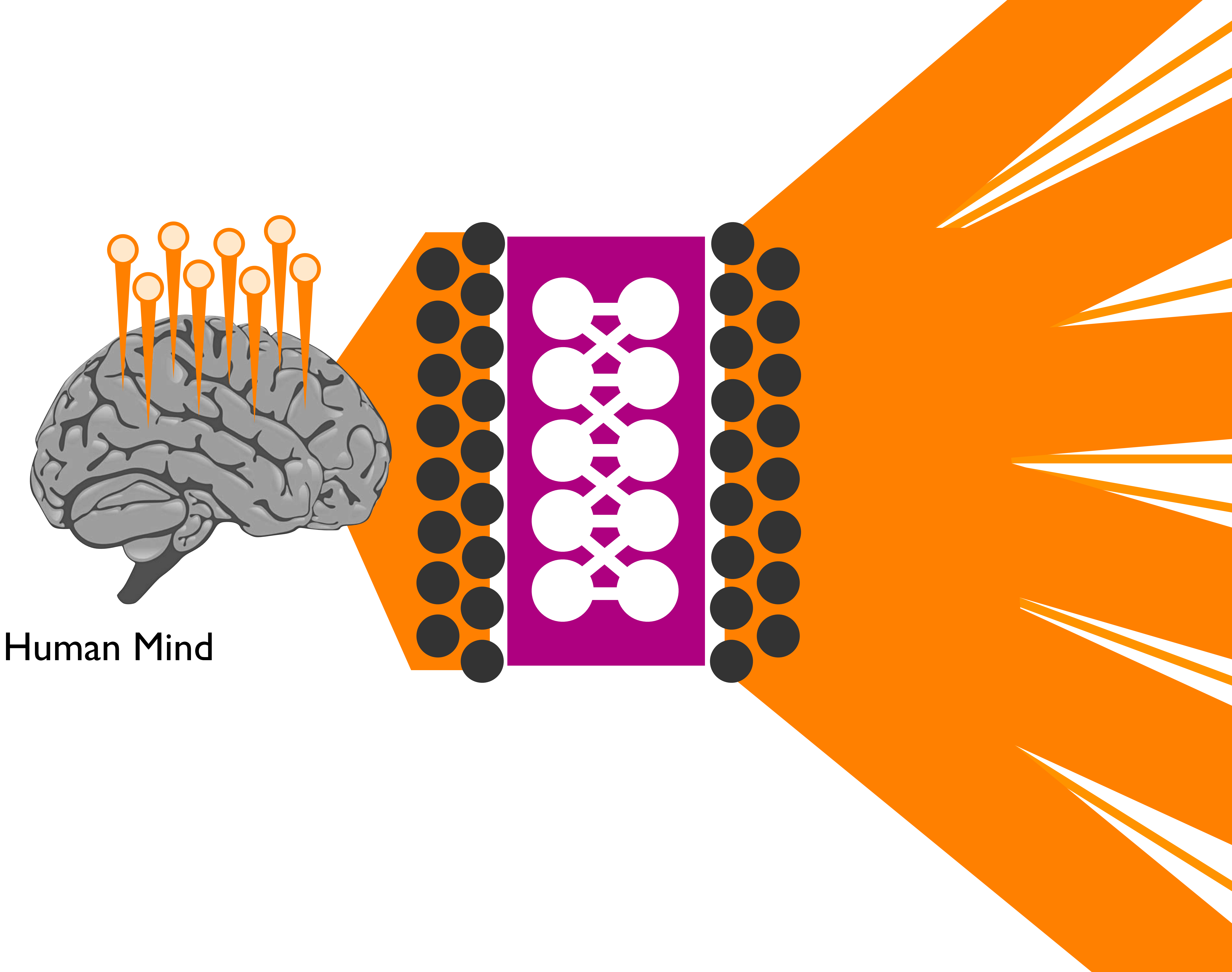
Communicative capital: work expended to build up knowledge about internal and external signals

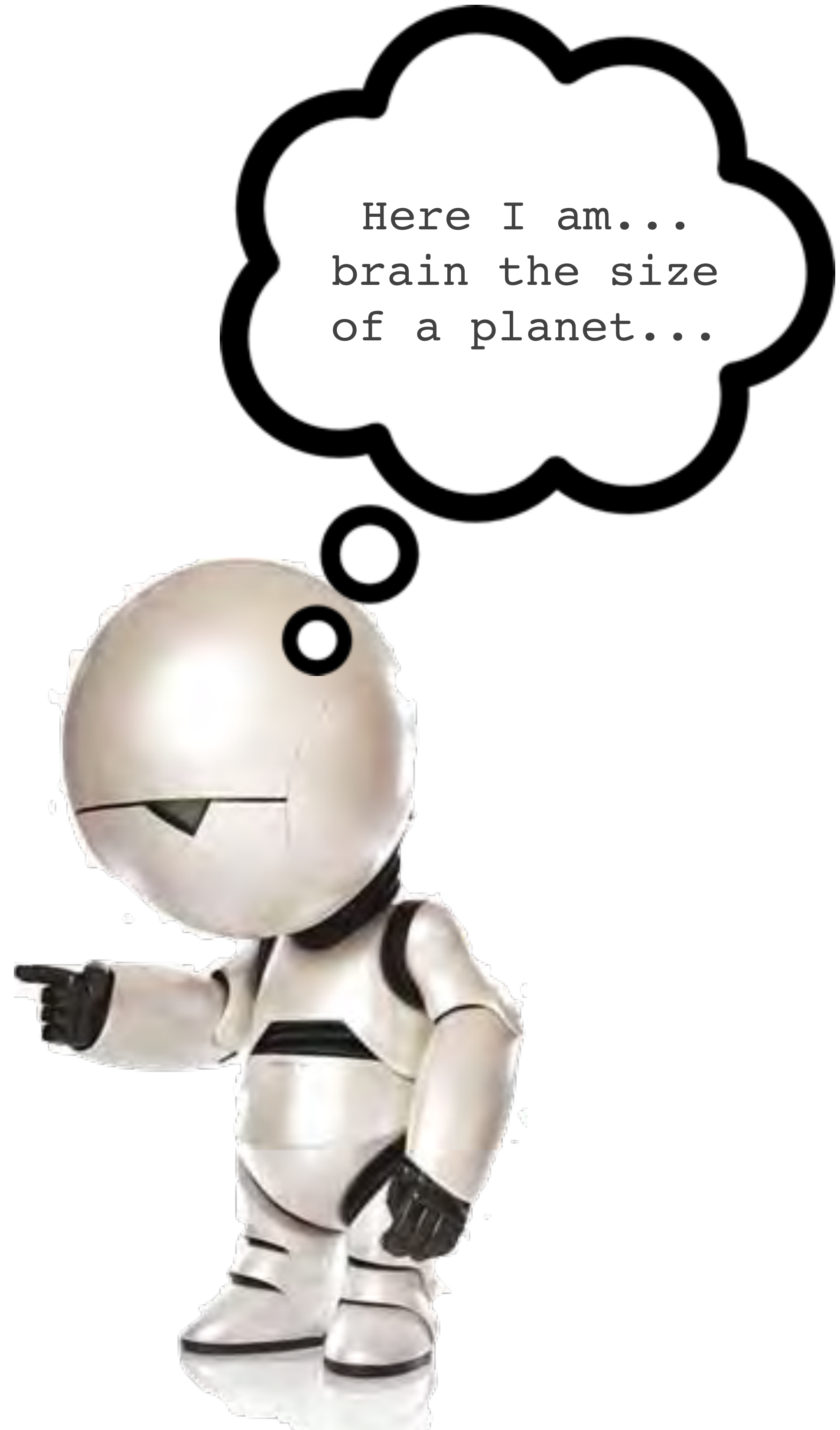


Pilarski Lab, Feb. 25, 2016
(Pilarski and Sherstan, *BioRob*, 2016)


Robot
Human Body


Human Mind
Synthetic Body


Human Mind



Marvin the paranoid android from THHGTTG.

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Anna Koop
… and more!

RL & AI

BLINC

ACELab
ACTION in COMPLEX ENVIRONMENTS

SMART NETWORK
Sensory Motor Adaptive Rehabilitation Technology

Funders and Partners

Canada Research Chairs

amii

AICML ALBERTA INNOVATES CENTRE FOR MACHINE LEARNING

Canada Foundation for Innovation

Alberta Innovates Technology Futures

NSERC CRSNG

URi

GLENROSE REHABILITATION • HOSPITAL FOUNDATION

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UNIVERSITY OF ALBERTA FACULTY OF MEDICINE & DENTISTRY

UNIVERSITY OF ALBERTA FACULTY OF REHABILITATION MEDICINE

DARPA

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Computer Science > Artificial Intelligence

Communicative Capital for Prosthetic Agents

Patrick M. Pilarski, Richard S. Sutton, Kory W. Mathewson, Craig Sherstan, Adam S. R. Parker, Ann L. Edwards

(Submitted on 10 Nov 2017)

This work presents an overarching perspective on the role that machine intelligence can play in enhancing human abilities, especially those that have been diminished due to injury or illness. As a primary contribution, we develop the hypothesis that assistive devices, and specifically artificial arms and hands, can and should be viewed as agents in order for us to most effectively improve their collaboration with their human users. We believe that increased agency will enable more powerful interactions between human users and next generation prosthetic devices, especially when the sensorimotor space of the prosthetic technology greatly exceeds the conventional control and communication channels available to a prosthetic user. To more concretely examine an agency-based view on prosthetic devices, we propose a new schema for interpreting the capacity of a human-machine collaboration as a function of both the human's and machine's degrees of agency. We then introduce the idea of communicative capital as a way of thinking about the communication resources developed by a human and a machine during their ongoing interaction. Using this schema of agency and capacity, we examine the benefits and disadvantages of increasing the agency of a prosthetic limb. To do so, we present an analysis of examples from the literature where building communicative capital has enabled a progression of fruitful, task-directed interactions between prostheses and their human users. We then describe further work that is needed to concretely evaluate the hypothesis that prostheses are best thought of as agents. The agent-based viewpoint developed in this article significantly extends current thinking on how best to support the natural, functional use of increasingly complex prosthetic enhancements, and opens the door for more powerful interactions between humans and their assistive technologies.

Comments: 33 pages, 10 figures; unpublished technical report undergoing peer review
Subjects: **Artificial Intelligence (cs.AI)**; Human-Computer Interaction (cs.HC); Learning (cs.LG)
Cite as: arXiv:1711.03676 **[cs.AI]**
(or arXiv:1711.03676v1 **[cs.AI]** for this version)

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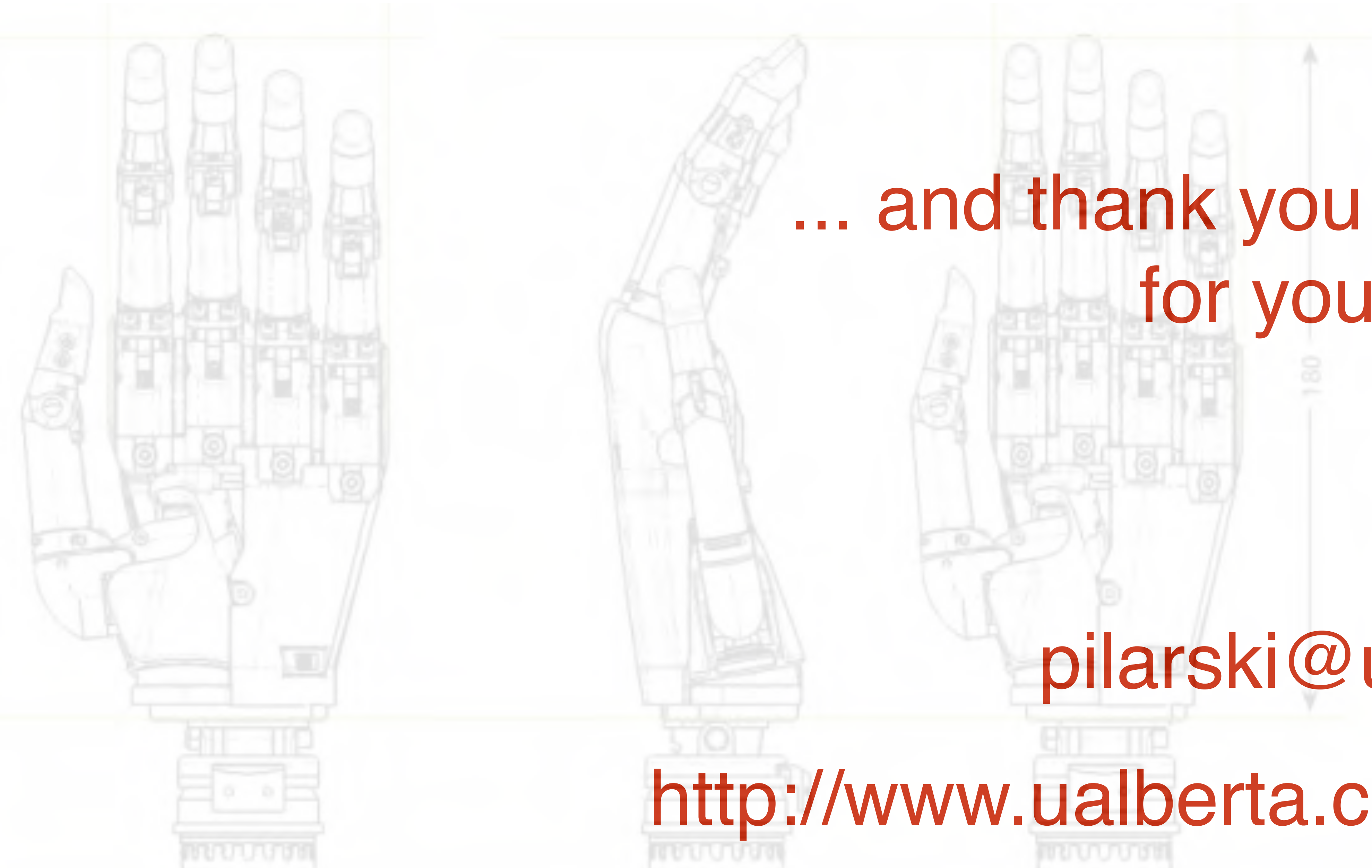
Questions



... and thank you very much
for your attention.

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http://www.ualberta.ca/~pilarski/