AI
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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STICK
{a stick, branch, twig}
{force multiplier, remote actuation}

STICK
{a stick, branch, twig}
SPINNING WHEEL

{animal fur, plant matter}  >>  {thread, yarn}
... and, in short order
Here I am... brain the size of a planet...

Marvin the paranoid android from THHGTG.
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).
Whee! I can pee on carpets!

Outside. Pee outside. Seriously: pee outside!
Upper-limb Prosthetics
(from cables-and-hooks to bionic bodies)
Advanced bionic technology exists ...

... but there are barriers to using it.

**Function Control Feedback**

(Peerdemian 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
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.

... 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
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
Autonomous Switching
(learning and unlearning automatic control actions)

Realized capacity

Expert

Non-Expert

Manual Interactions

Best possible:
0 manual switches per iteration

5-20 manual switches

20-50 manual switches

Towards Smarter Parts

moving beyond engineered solutions and towards more general prosthetic intelligence
Communicative capital: work expended to build up knowledge about internal and external signals
Human Mind

Synthetic Body
Human Mind
Here I am... brain the size of a planet...

Marvin the paranoid android from THHGGTTG.
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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.

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Questions

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

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