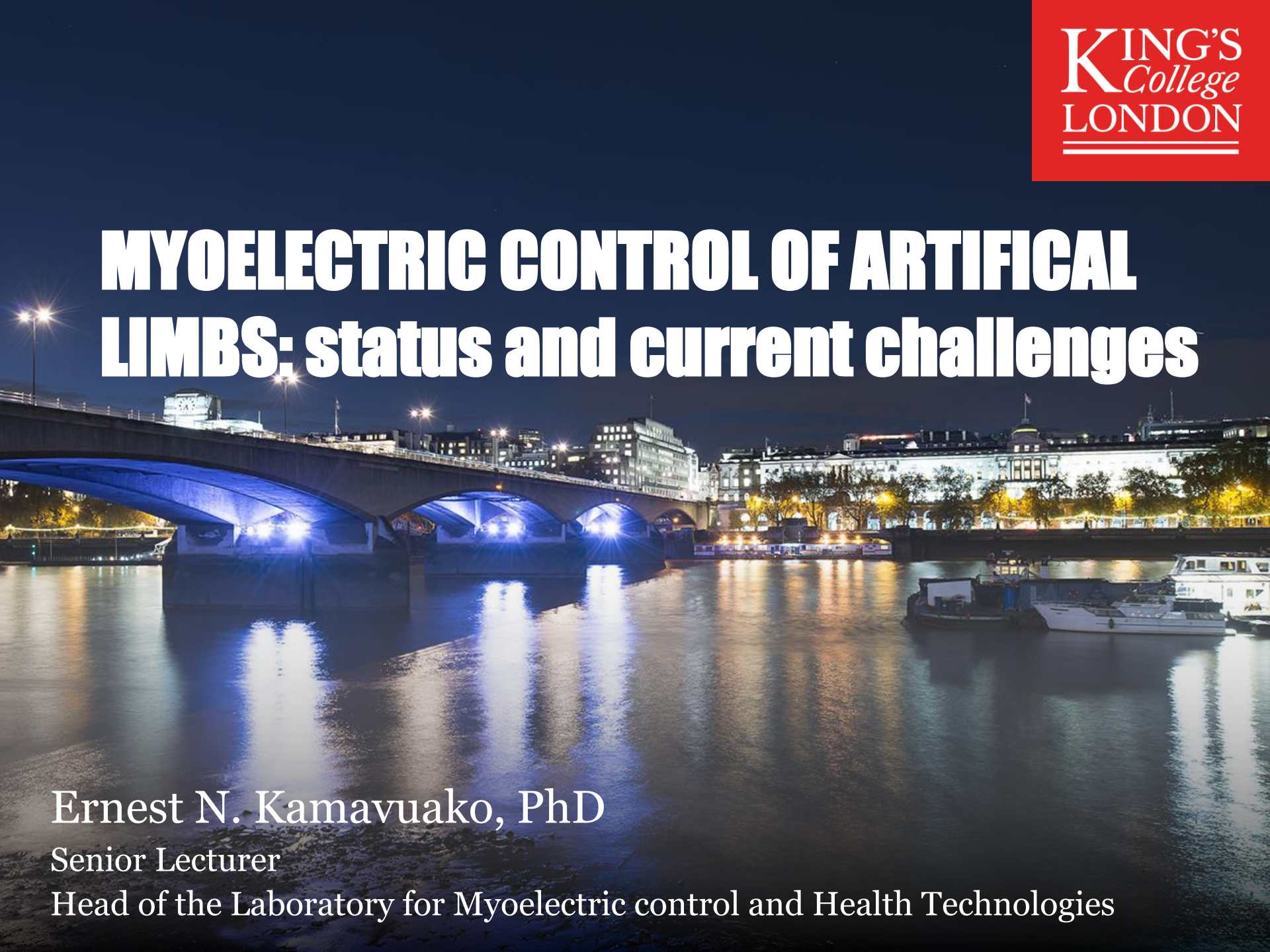
MYOELECTRIC CONTROL OF ARTIFICAL LIMBS: status and current challenges

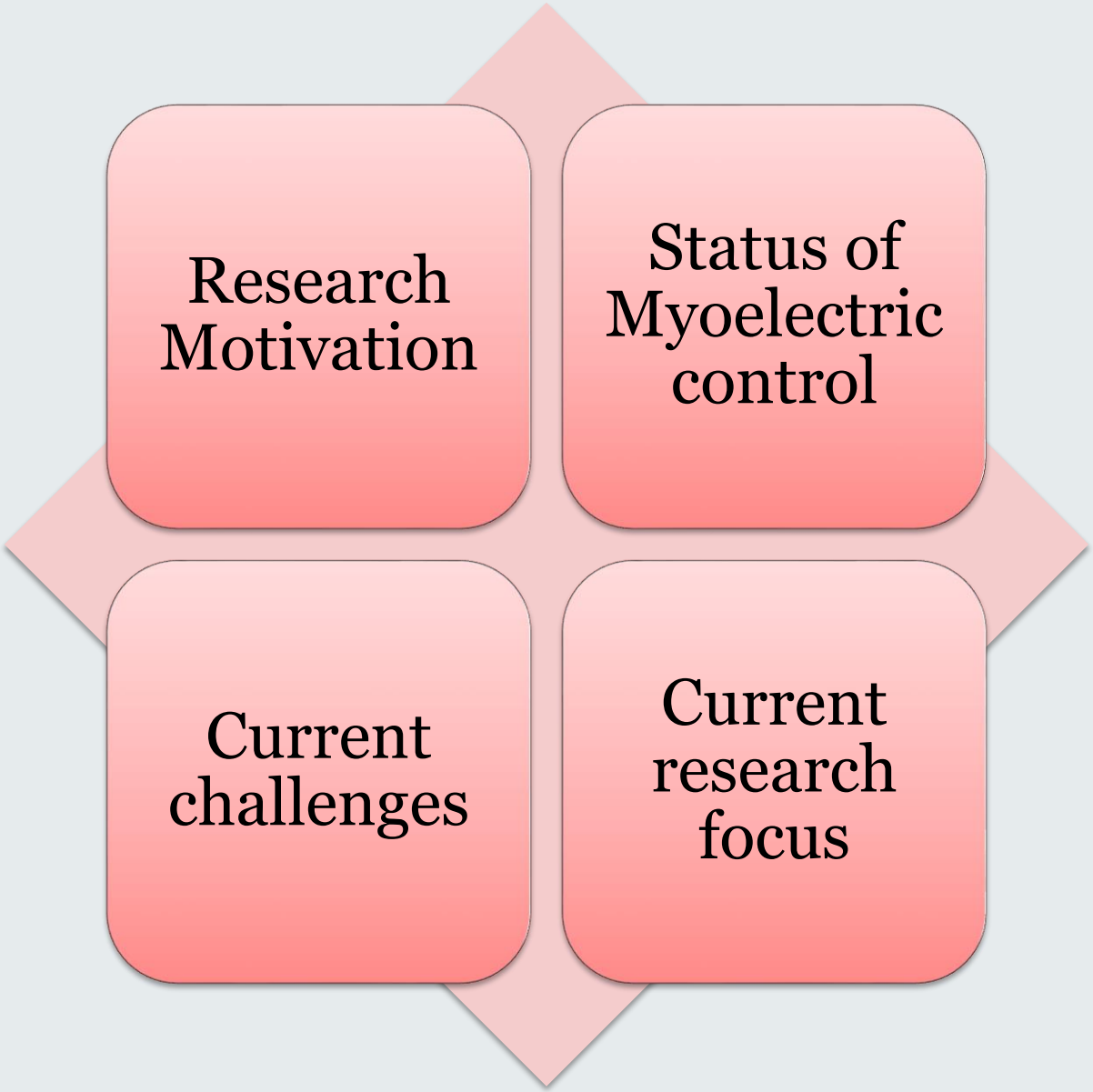


Ernest N. Kamavuako, PhD
Senior Lecturer
Head of the Laboratory for Myoelectric control and Health Technologies

About me

- Joined King's College London as Senior Lecturer in the department of Informatics since October 2017.
- Previous: Associate Professor in the Department of Health Science and Technology, Aalborg University, Denmark
- PhD in Biomedical Engineering, Aalborg University, Denmark

About this lecture



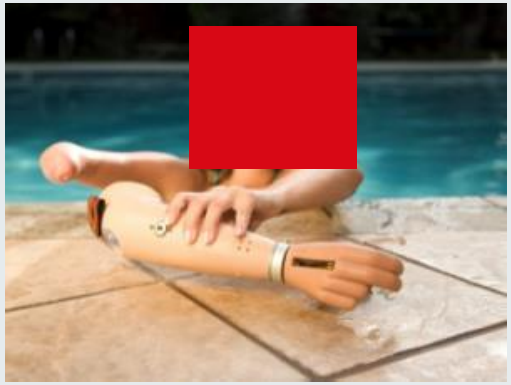
Motivations

- 5-6,000 major limb amputations are performed every year in the UK (limbless statistics 2013)
- Approx. 185.000 in USA
- Lower and **upper limb**

FootcareMD

Racheldavis1395.com

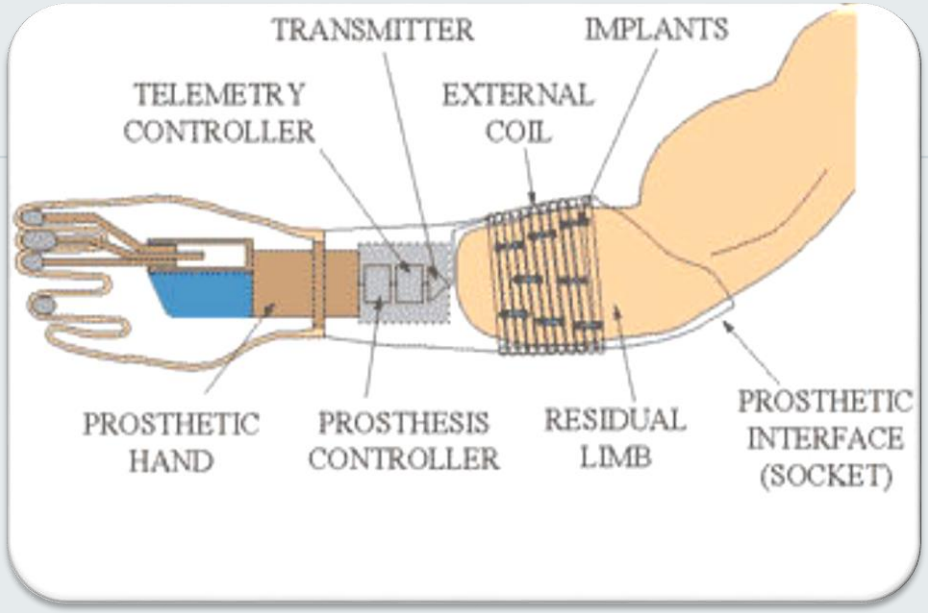
armswithinreach.org



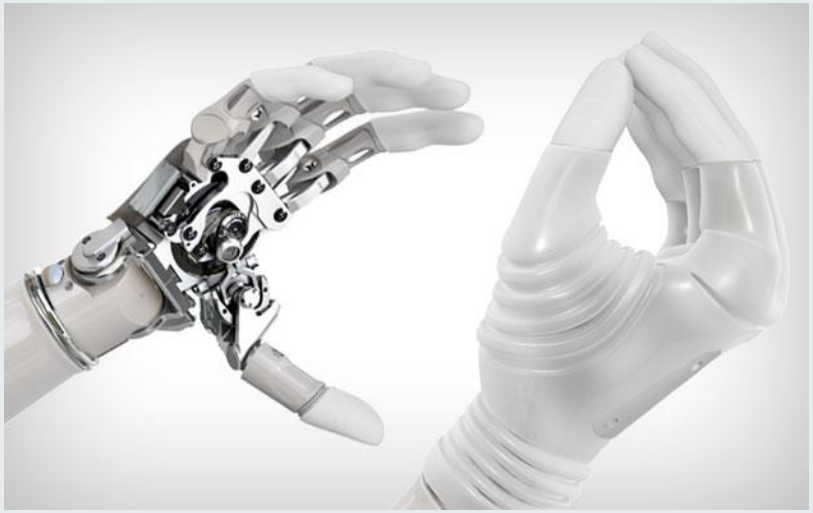
paradigmcorp.com

Motivations

Needs to regain functions
Replacement of limb
Artificial devices



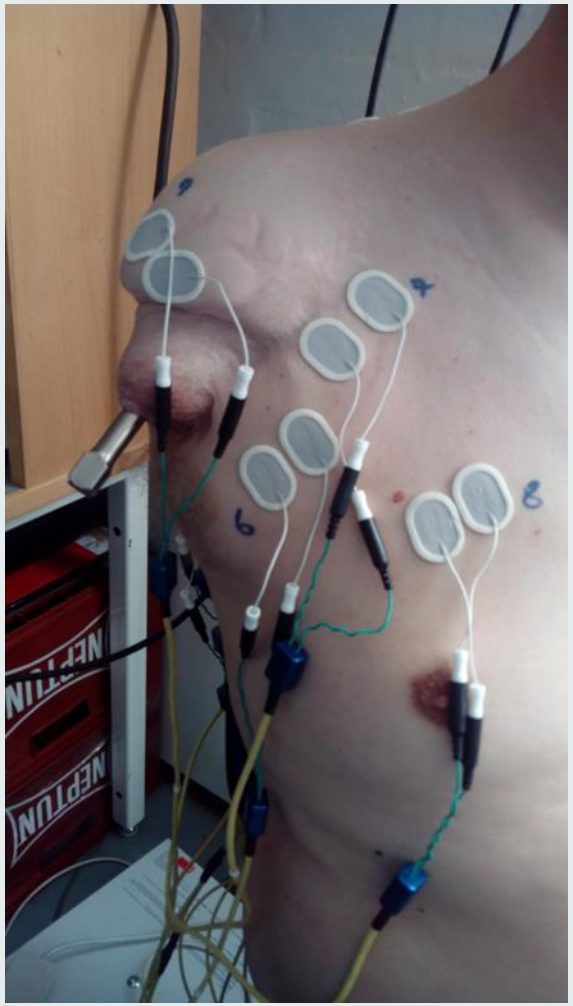
[Northwestern University, IL, USA]



[Michelangelo hand, ottobock]

[Bebionic hand, Bebionic]

Motivations

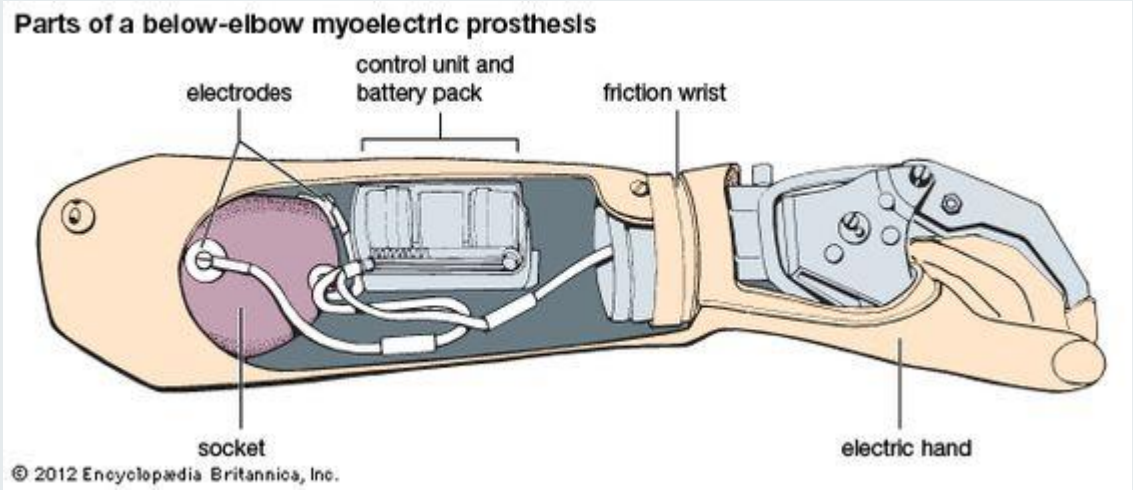


Different prostheses

Passive Prostheses

Body-powered prostheses

Myoelectric prostheses



Basic Principles

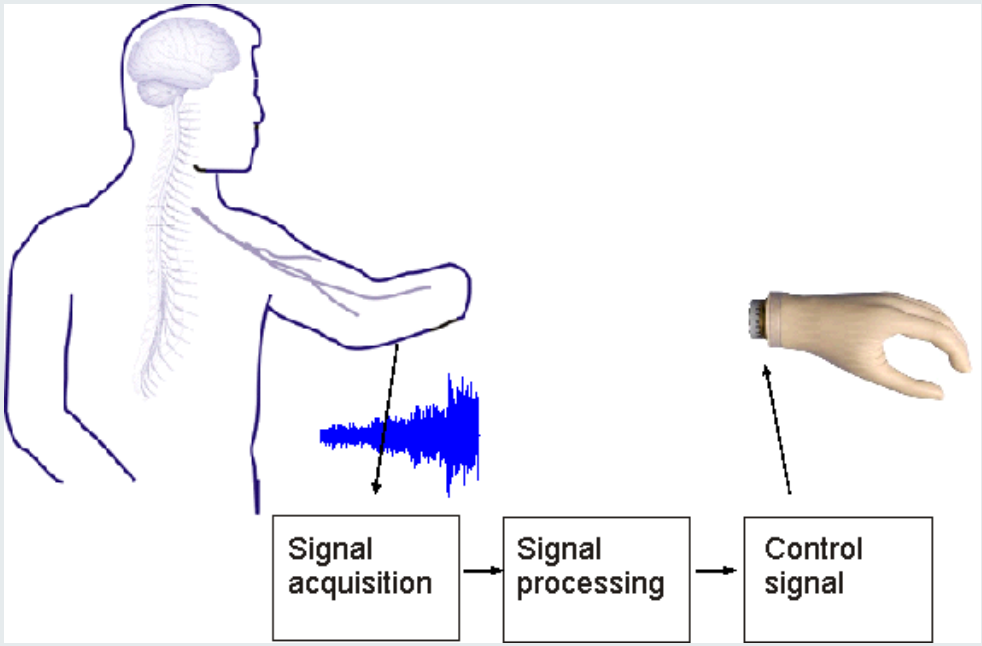
Electromyogram (Electric signals from muscles)

Process

Control

Commercial systems

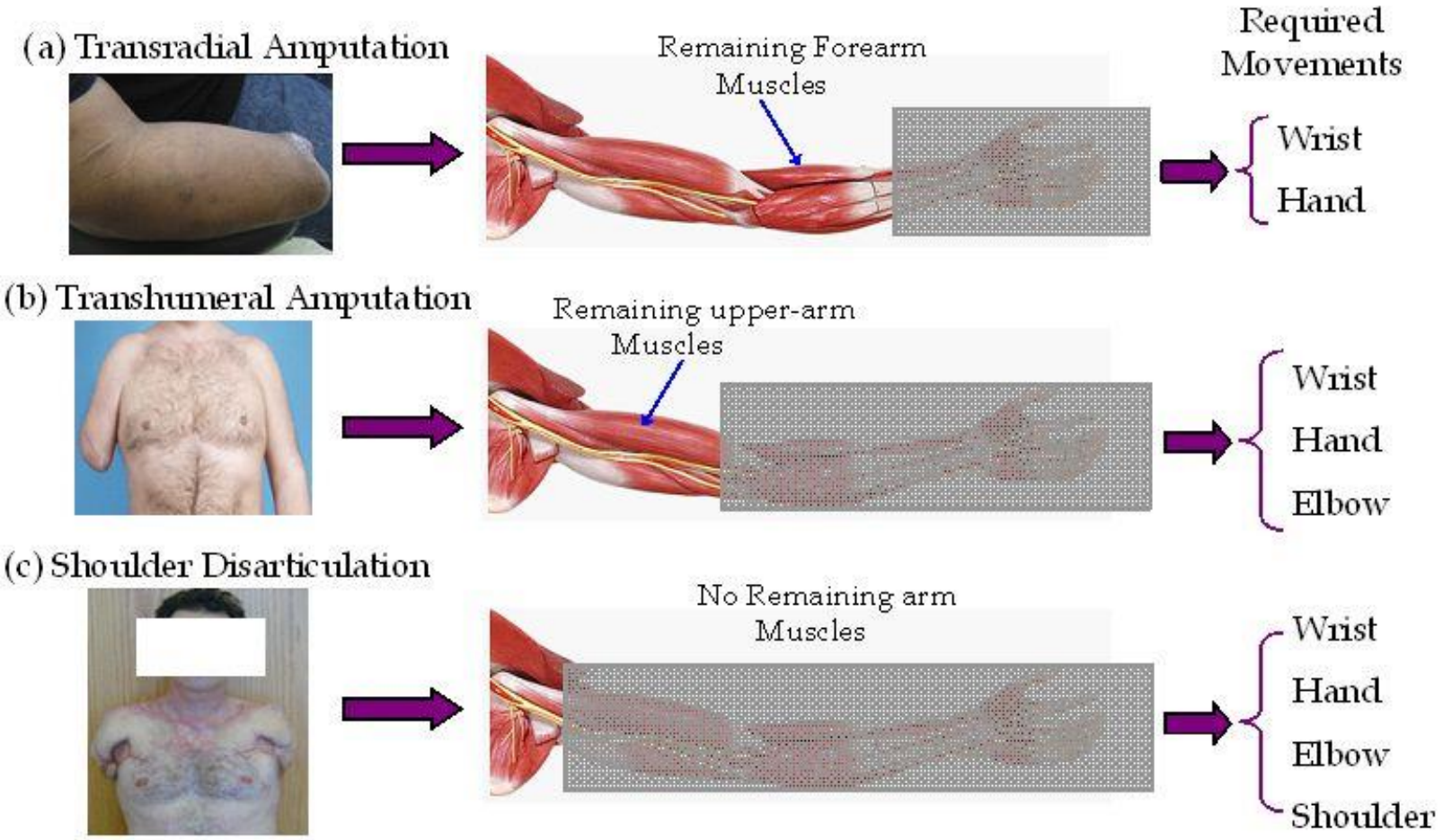
Myoelectric control



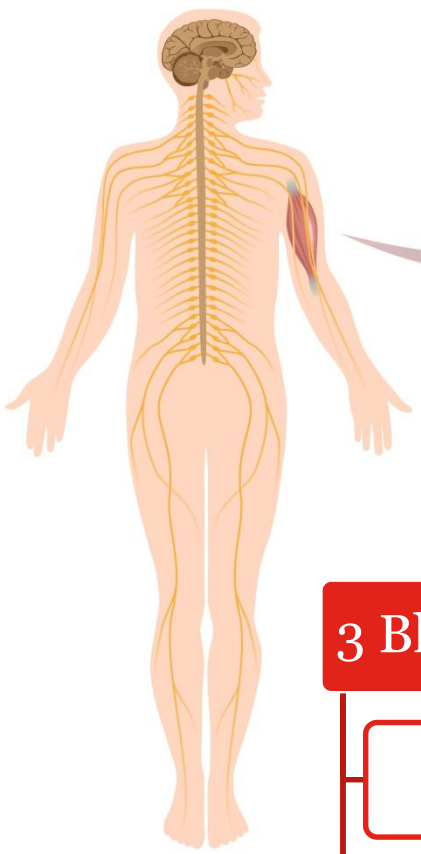
Stable => Functional => Robust

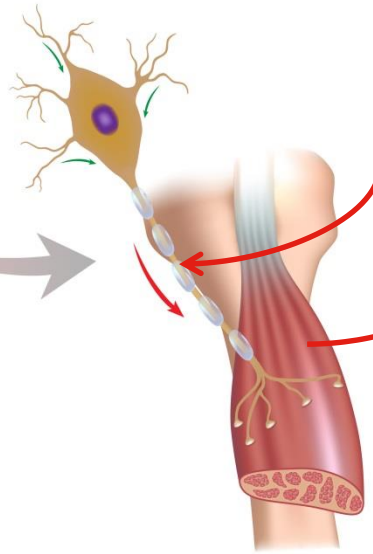
MYOELECTRIC CONTROL

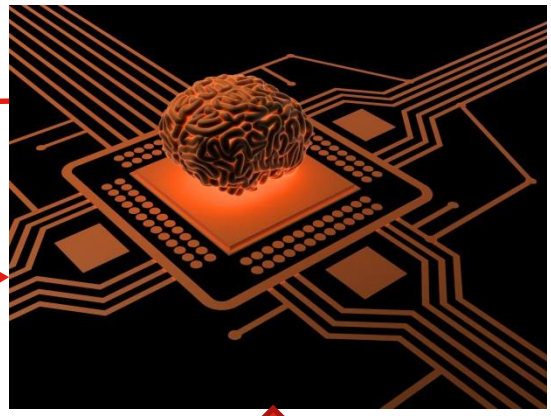
Restore functions after amputation of an upper limb



IDEAL RESTAURATION

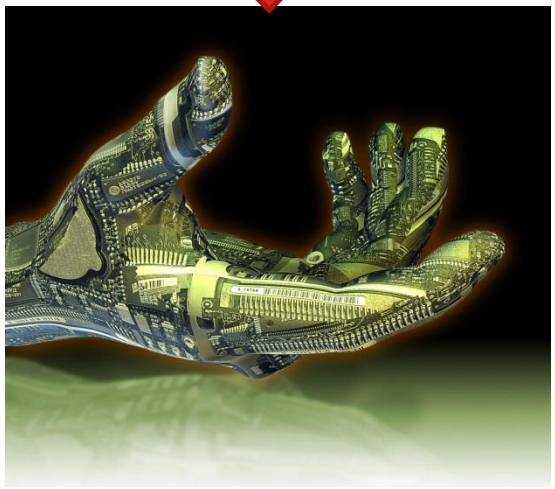






Advanced Processor
Able to understand and speak ***BRAINISH***

2 ways communication

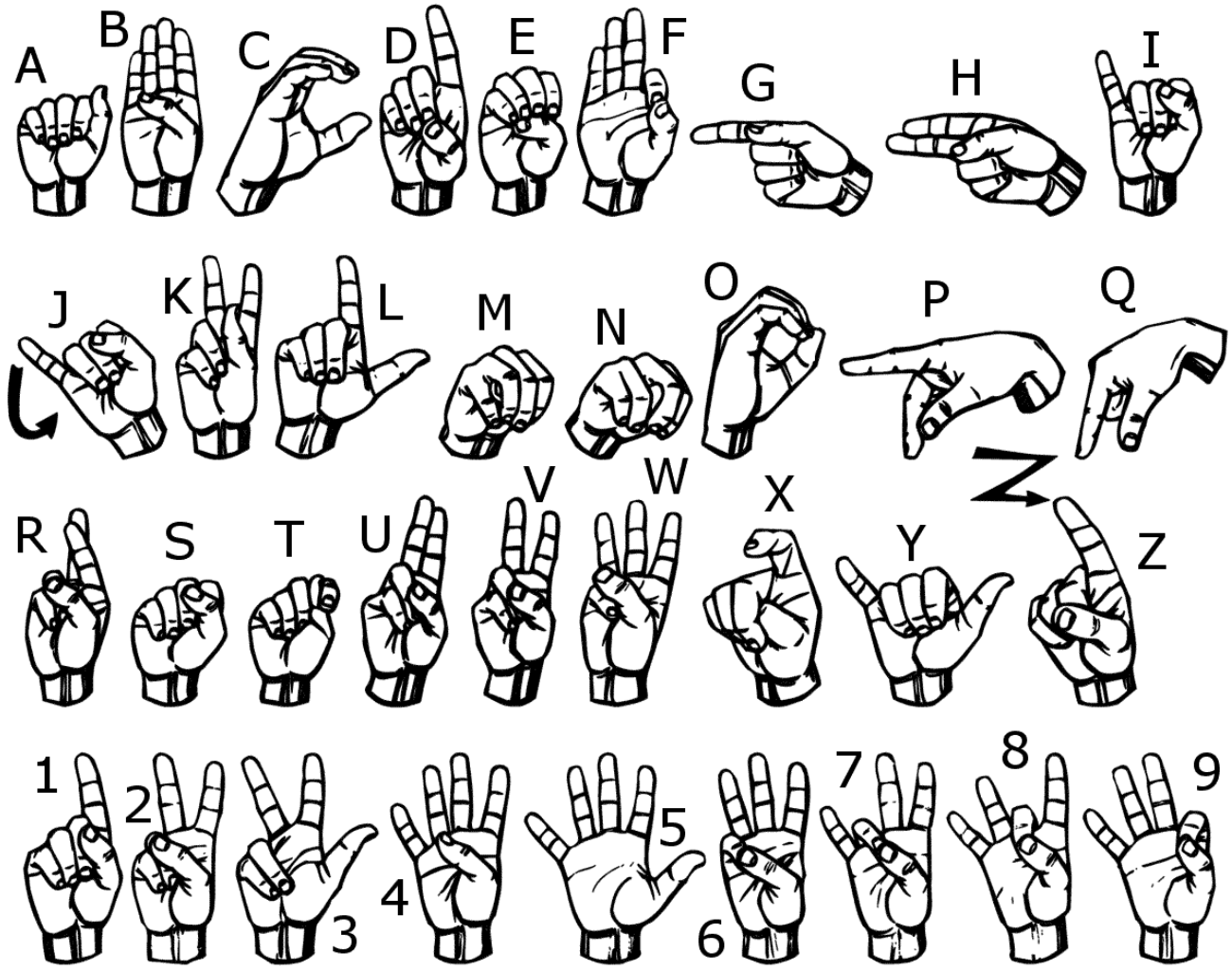


FEEDBACK
Advanced hand with sensors

3 Blocks

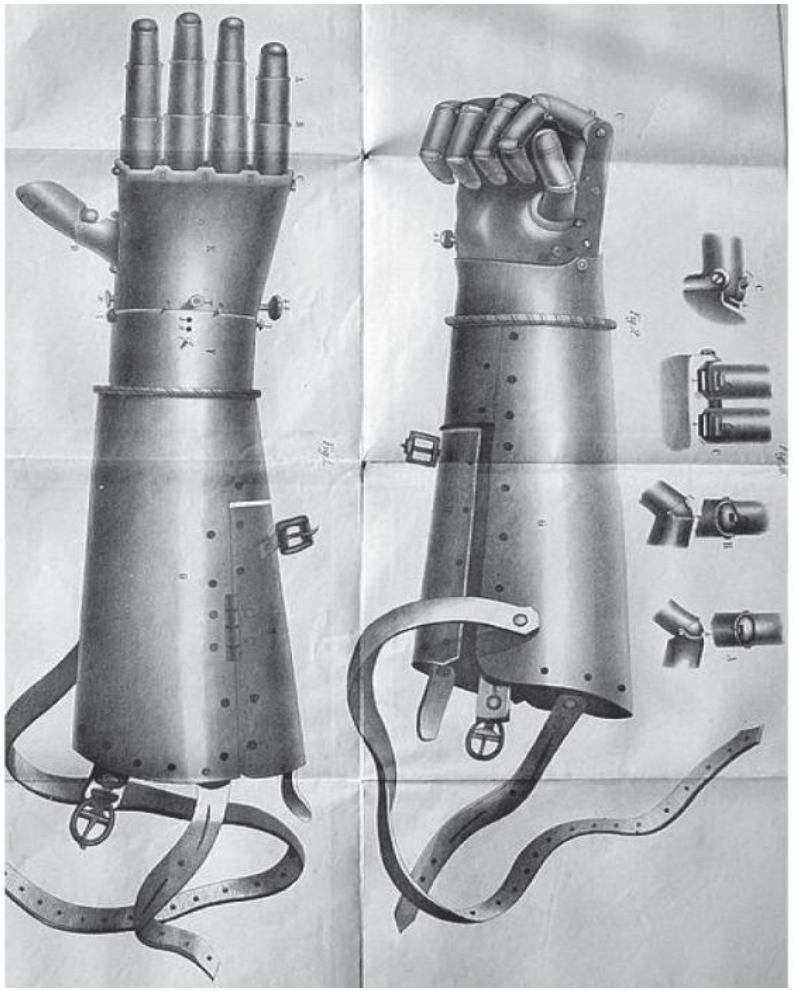
- **Mechanical**
- **Interfacing the body**
- **Feedback**

Mechanical challenges



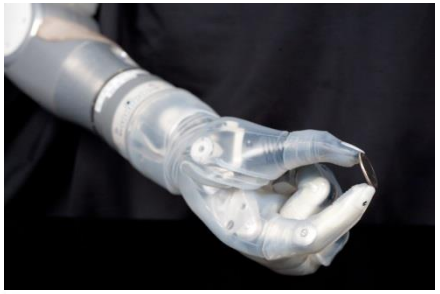
Fameous example of an early hand

- The iron hand of German knight Götz von Berlichingen [1]
- Götz lost his hand hand during the Siege of Landshut (ca. 1050) in Bavaria
- He got an iron hand with digits:
  - Passive flexion and extension at different joints



Current Advanced hands

- Significant improvements since 1960: Wrist DoFs, Individual fingers, sensors



DEKA

Bionic

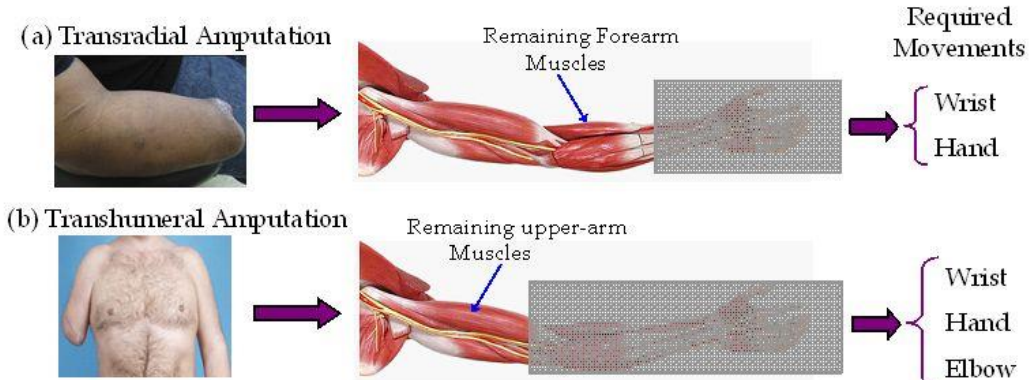
Otto Bockc

iLimb

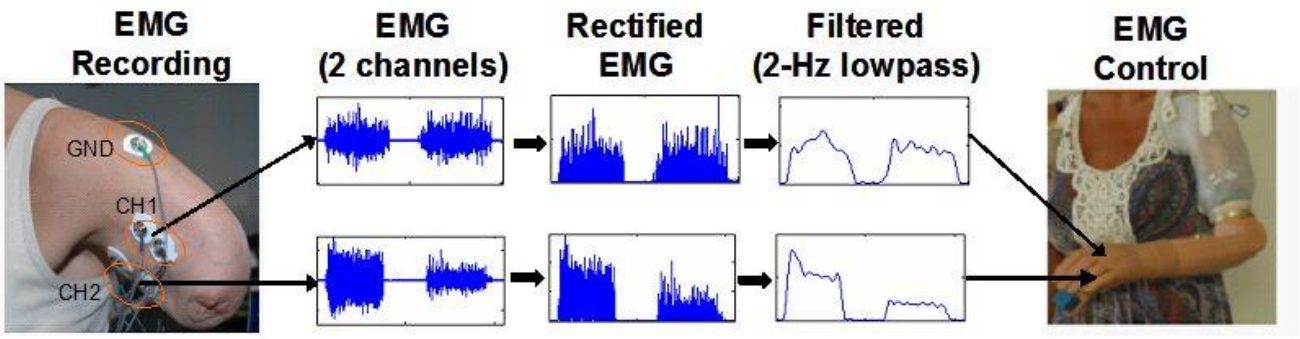
Evolution 2 by Vincent GmbH

THE BRAIN DOES NOT SPEAK ENGLISH

IT SPEAKS BRAINISH

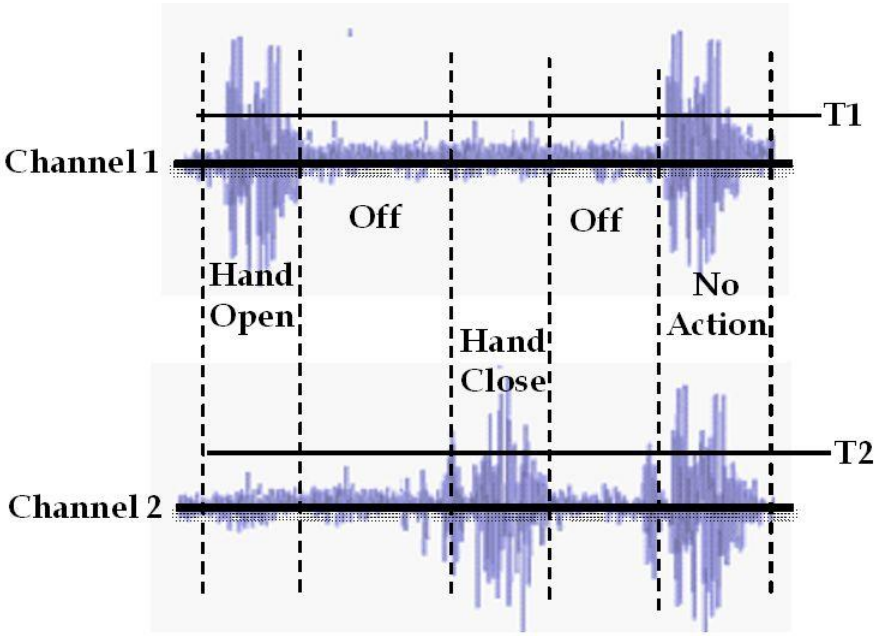


Our CLINICAL understanding of brainish



Direct control

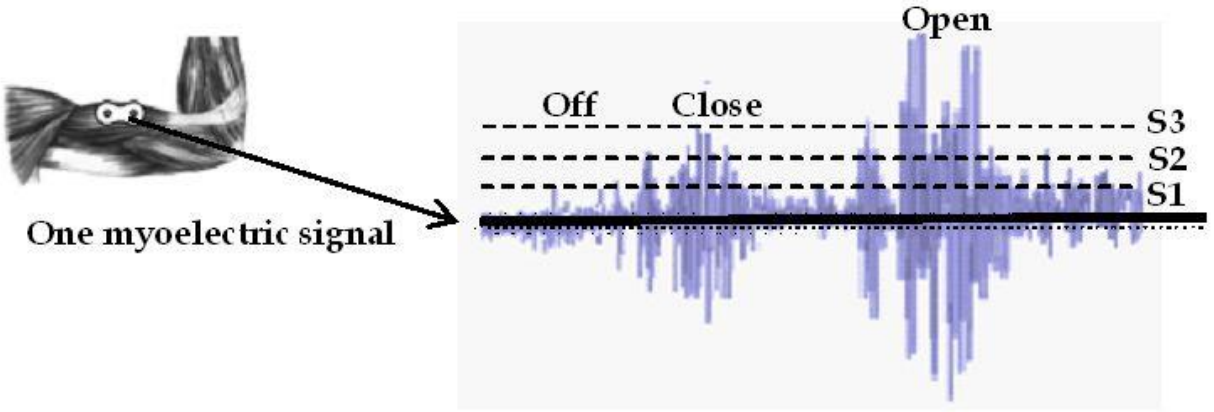
2 channel direct proportional control

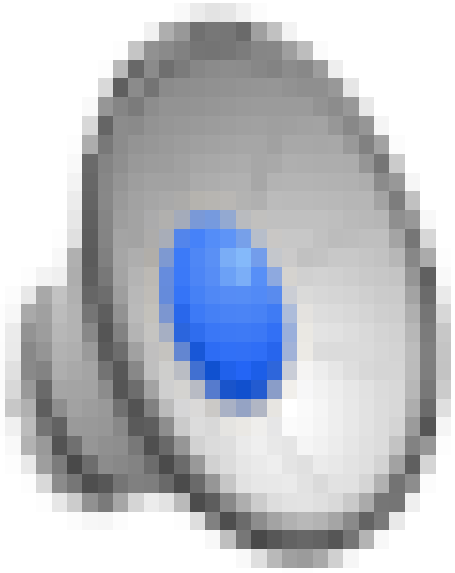


LIMITED NUMBER OF DOFs

MODE SWITCH

1 channel state control

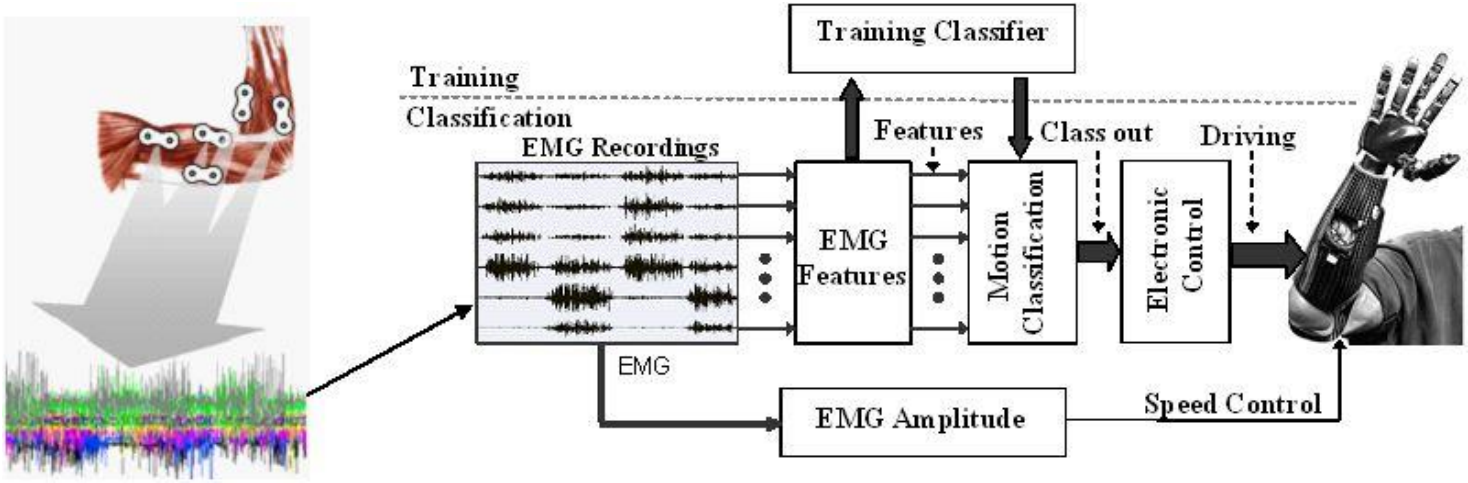




THE BRAIN DOES NOT SPEAK ENGLISH

IT SPEAKS BRAINISH

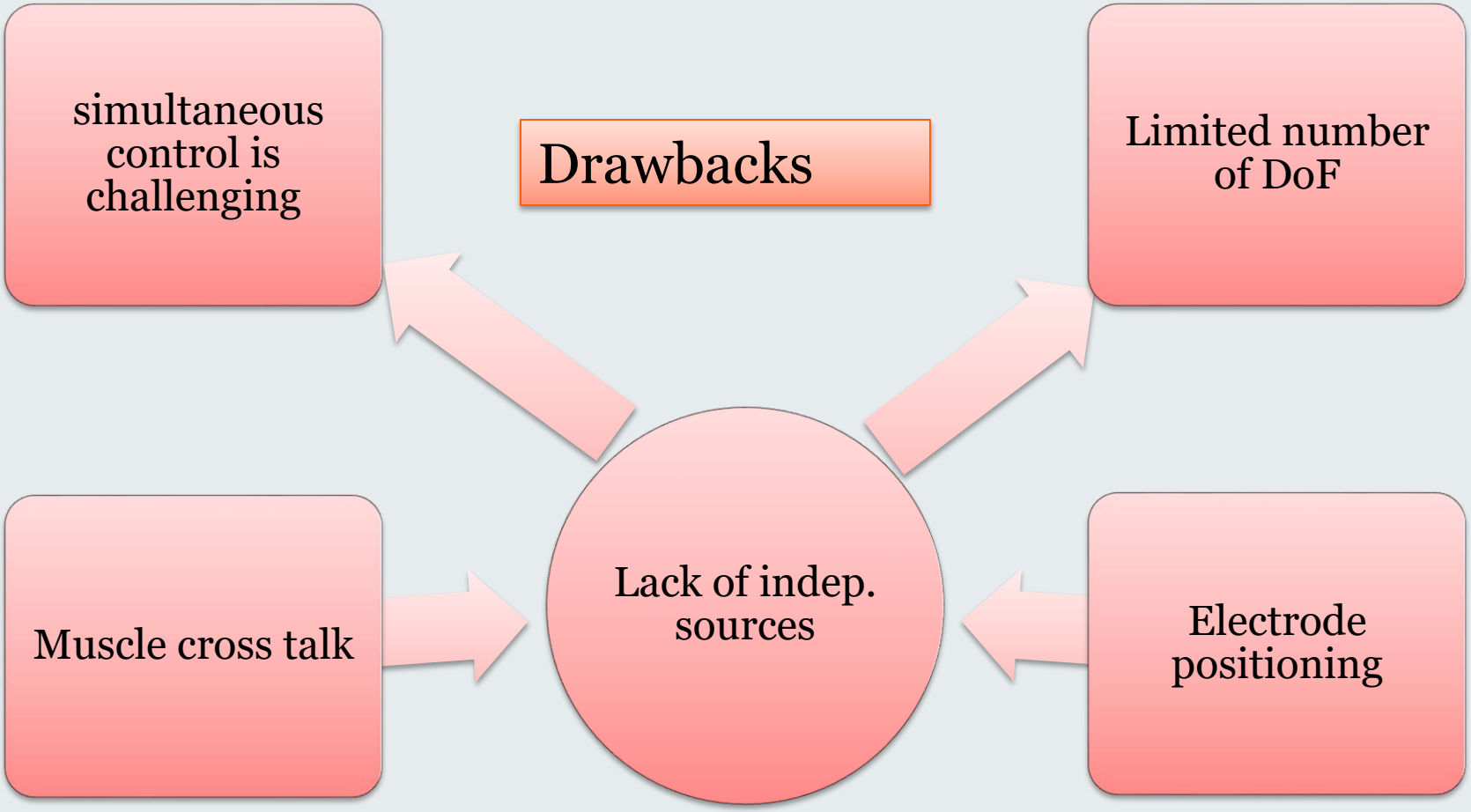
Our LABORATORY understanding of brainish



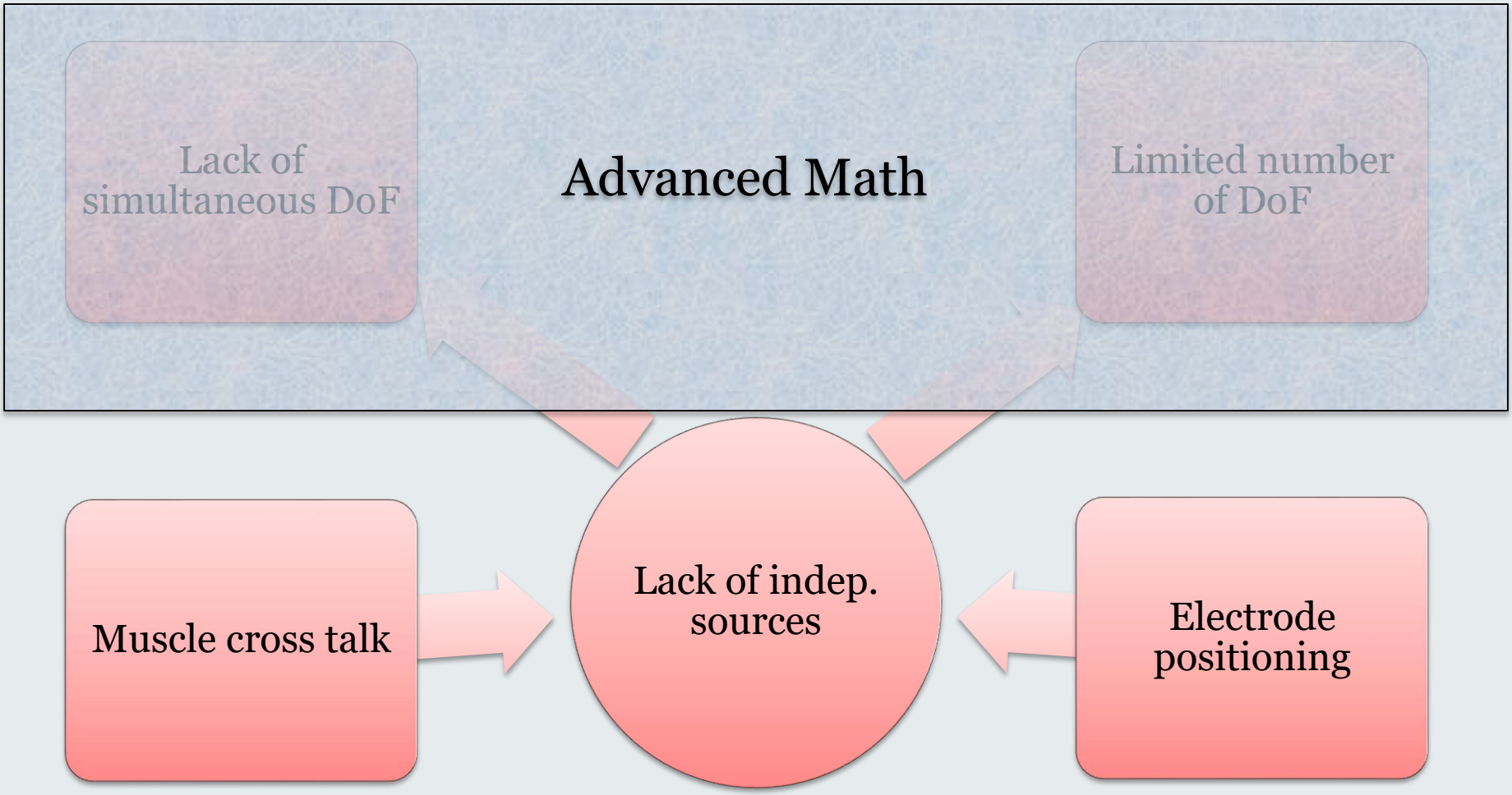
PATTERN RECOGNITION
MANY DOFs
SEQUENTIAL MOVEMENT
NEED FOR TRAINING

ELECTRODE SKIN PROBLEM
DAILY DONING AND DOFFING

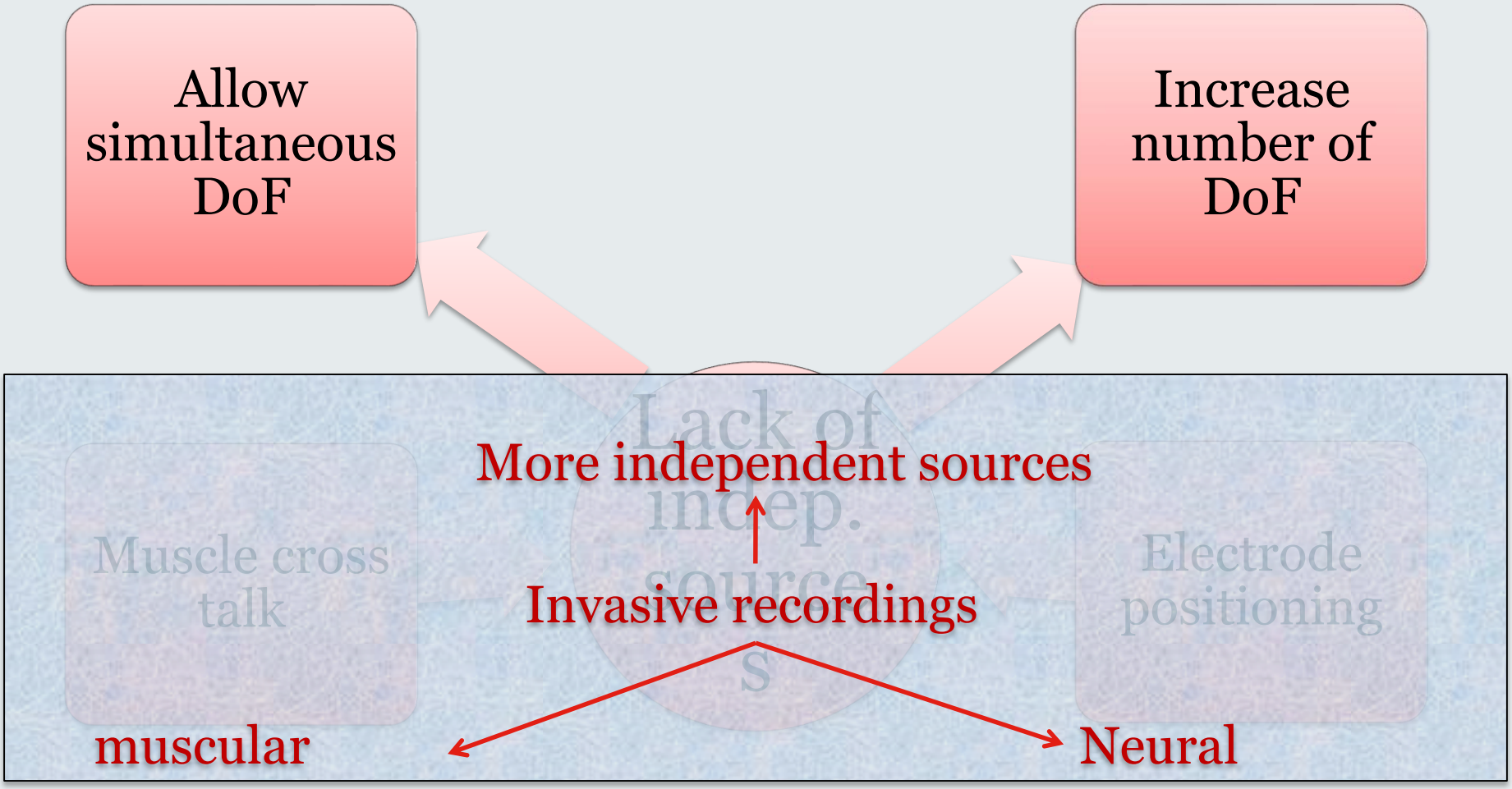
Surface EMG based prostheses



Artificial intelligence



Increased number of sources



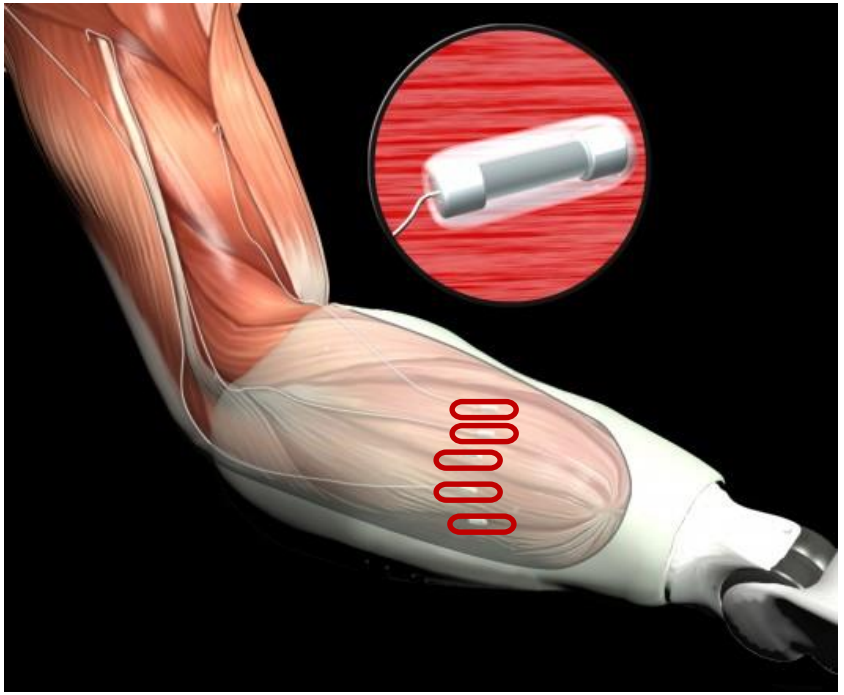
IMPLANTABLE MUSCLE ELECTRODES

- Focus of my research
- Get close to each individual source

- Increase the amount of information we listen to

- Studies to decode both movement intention and force information

- Chronic implant



DARPA

Effect of deep muscles

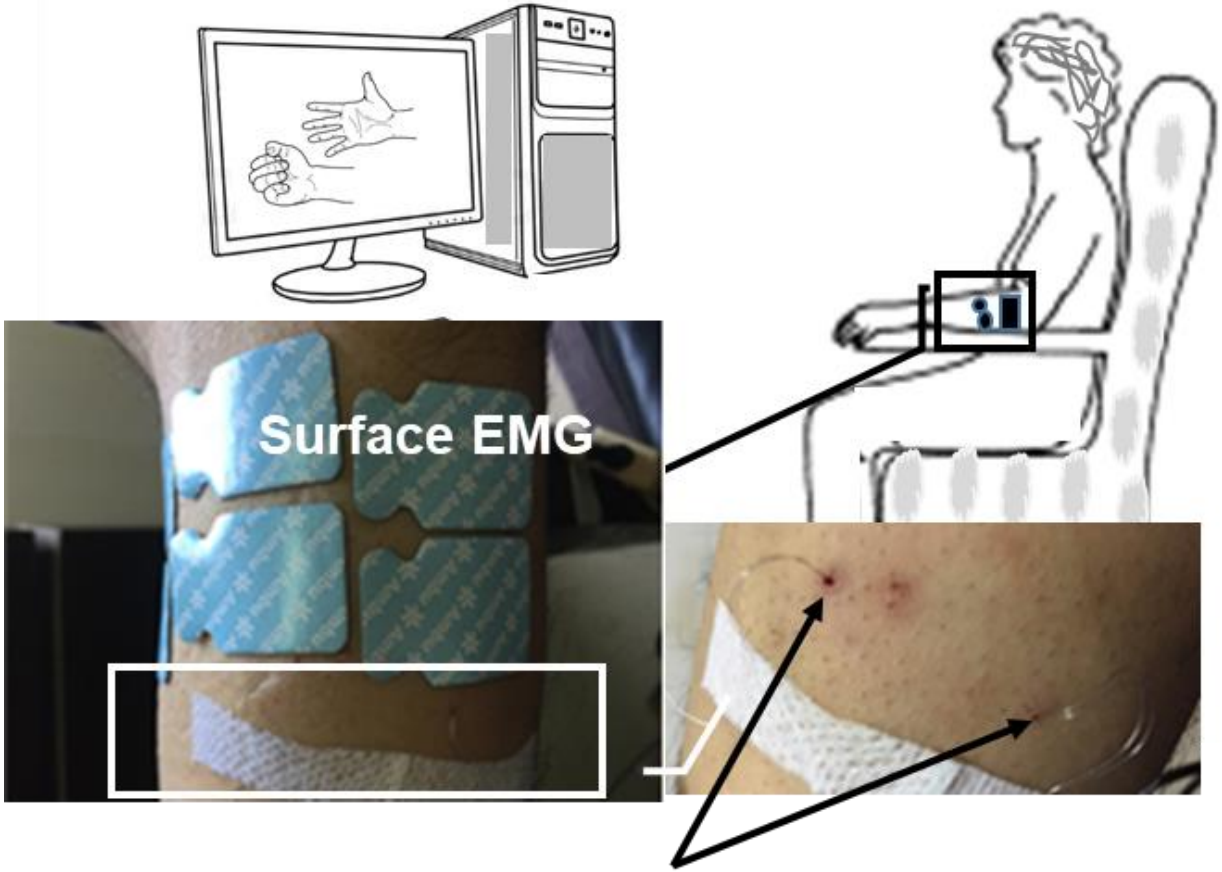
Background:

- Only superficial muscles are accessible with surface electrodes
- Some movements (wrist rotation) have specific deep muscles
- Wrist rotation is available in artificial limbs

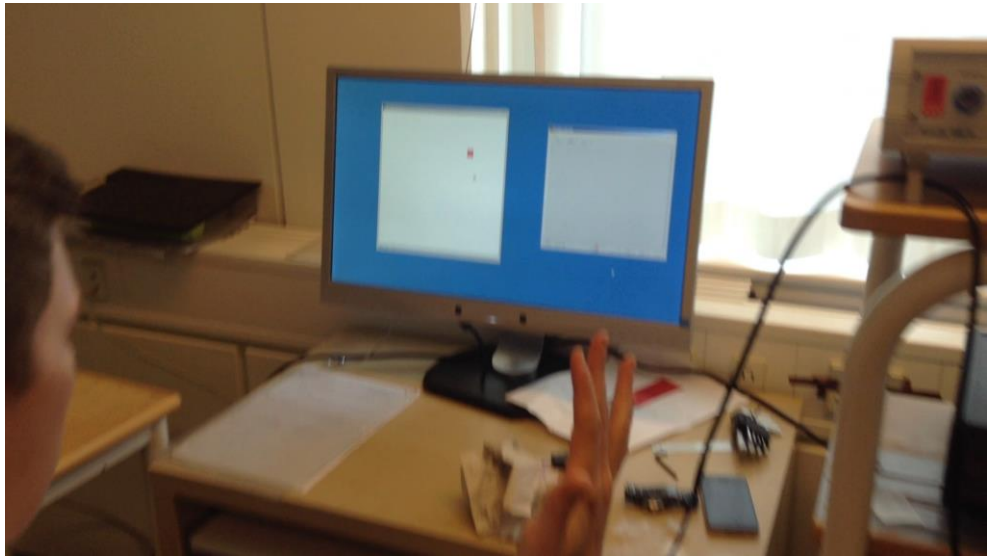
Aim:

Investigate whether signals from deep muscles may improve the control performance

Typical offline experimental setup



Real-time Experimental design
4 channels surface EMG against
2 surface and 2 intramuscular channels (ultrasound guided)



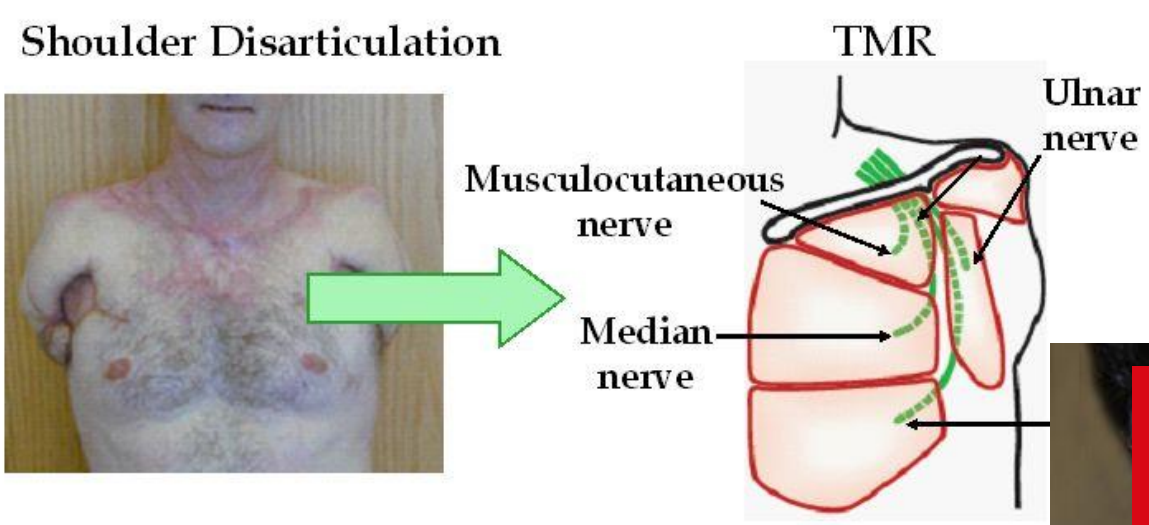
Real time test based on Fitts' Law with 4 motions: power grasp, hand open, wrist supination and pronation

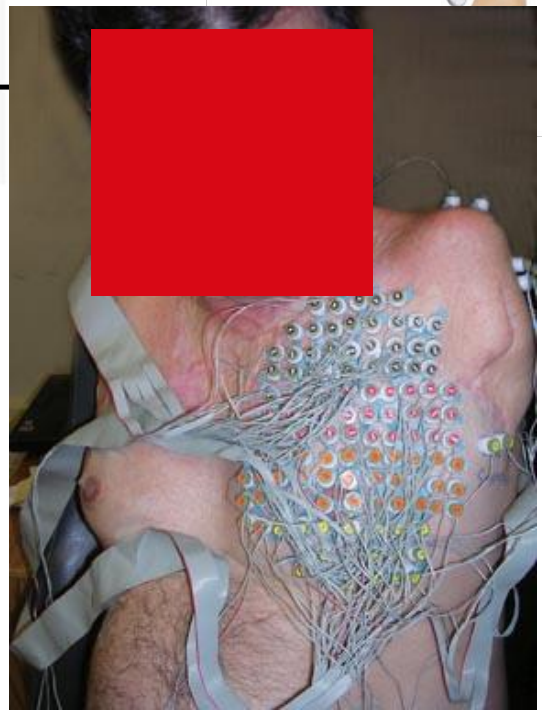
Higher level of amputation

- Accessible muscles?

Bionic

Target Muscle Reinnervation (TMR)





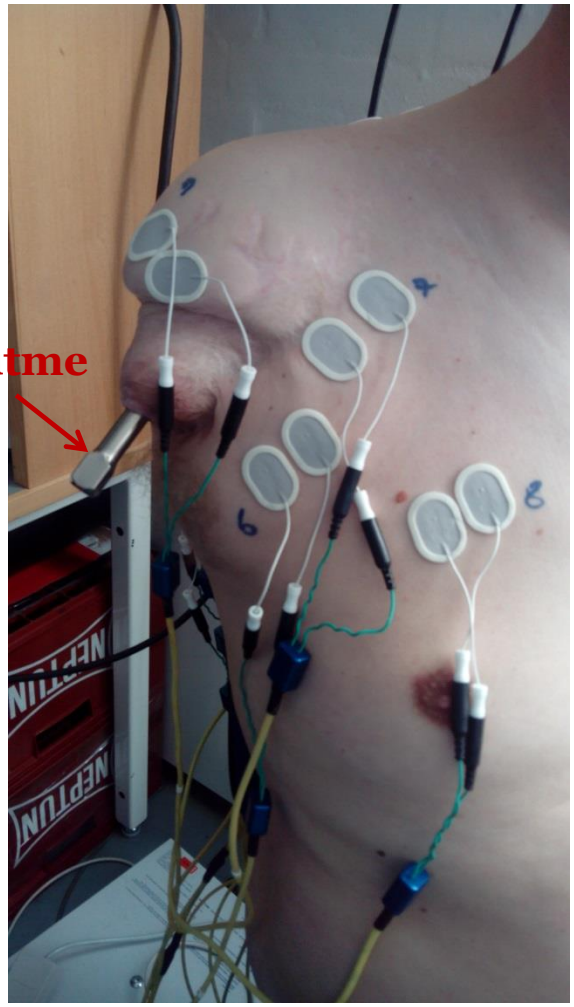
Sort of bionic reconstruction

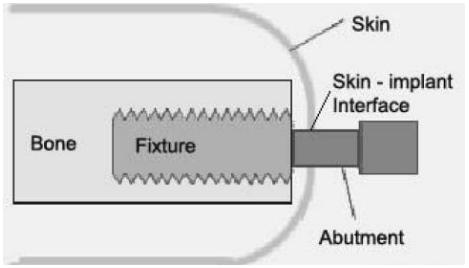
Courtesy of DEKA Research & Development and
The Rehabilitation Institute of Chicago

CASE STUDY:

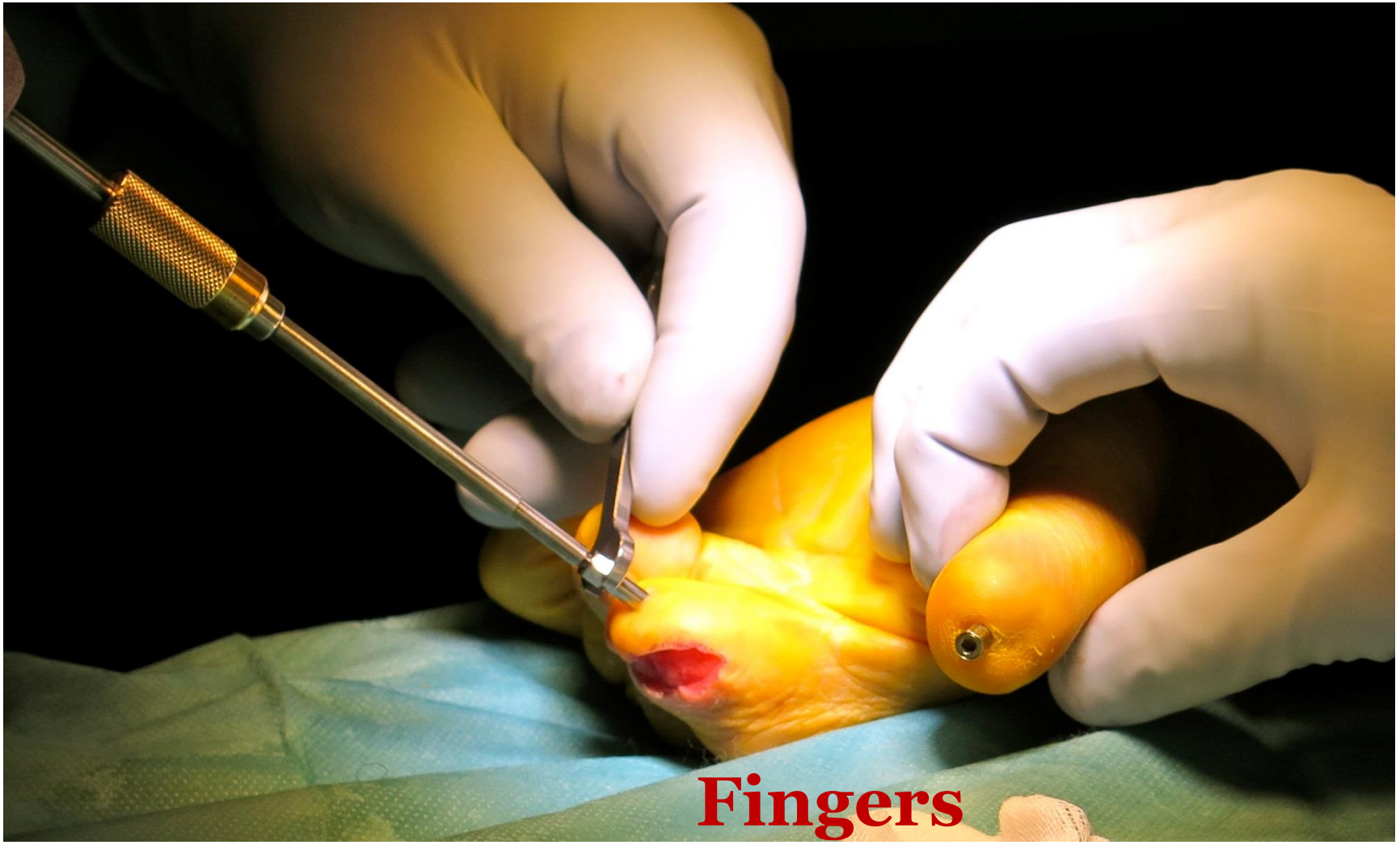
42-YEAR-OLD TRANSHUMERAL AMPUTEE

Patient with OsseoIntegration



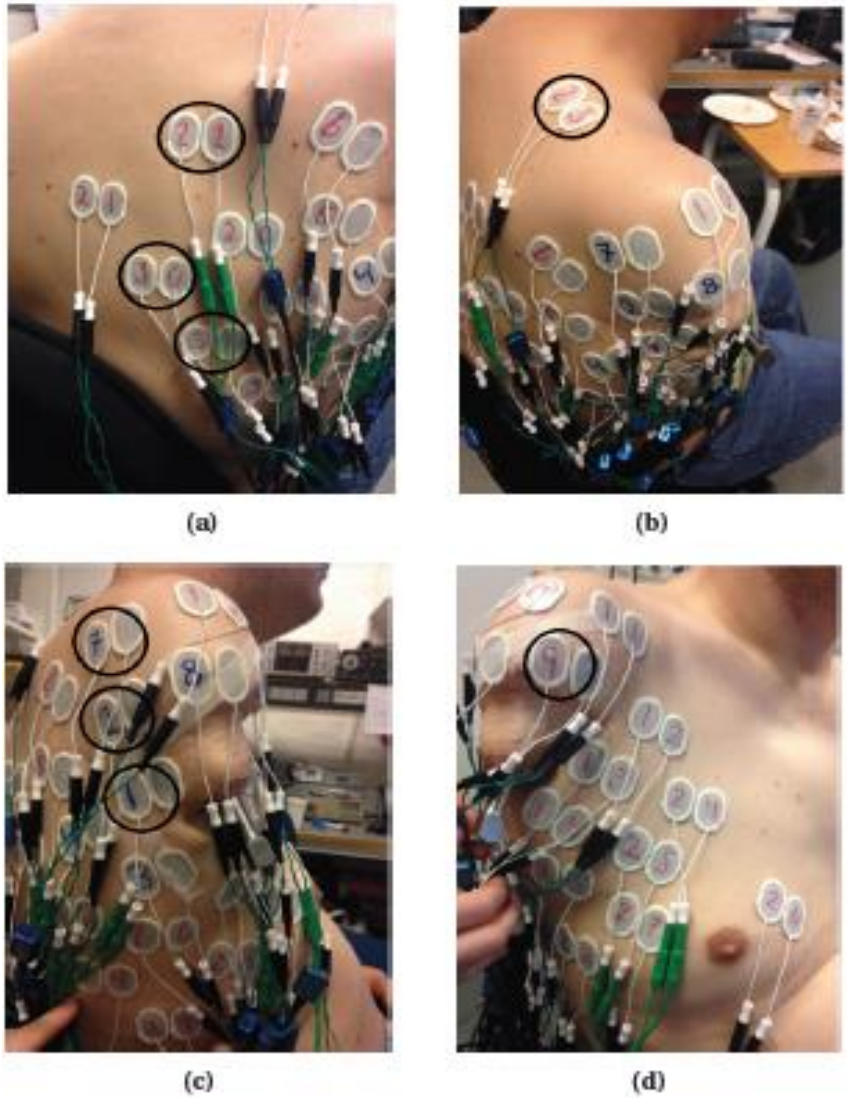


Information transfer from the body to the device

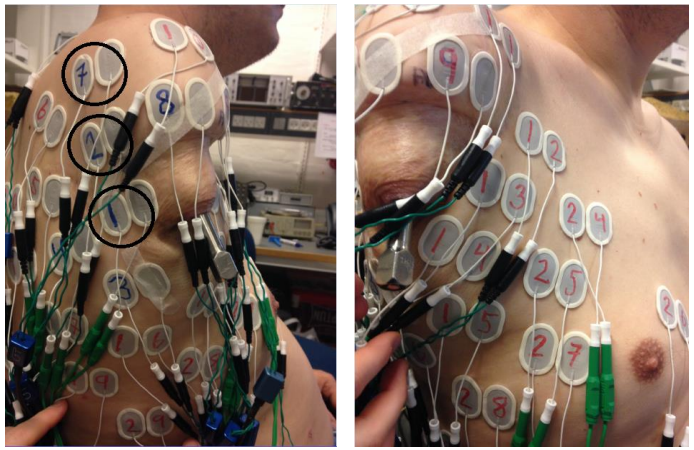

Fingers

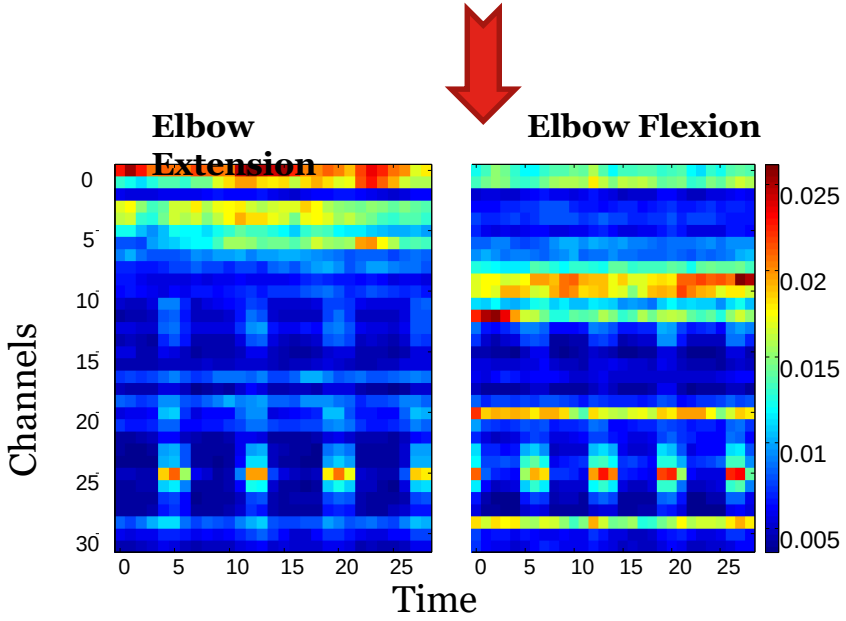
- One high level amputee
  - 42 years old
  - Amputated 22 years ago
- 32 channels surface EMG

- Phantom movements:
  - Elbow flexion (EF)
  - Elbow extension (EE)
  - Wrist supination (WS)
  - Wrist pronation (WP)
  - Hand open (HO)
  - Hand close (HC)

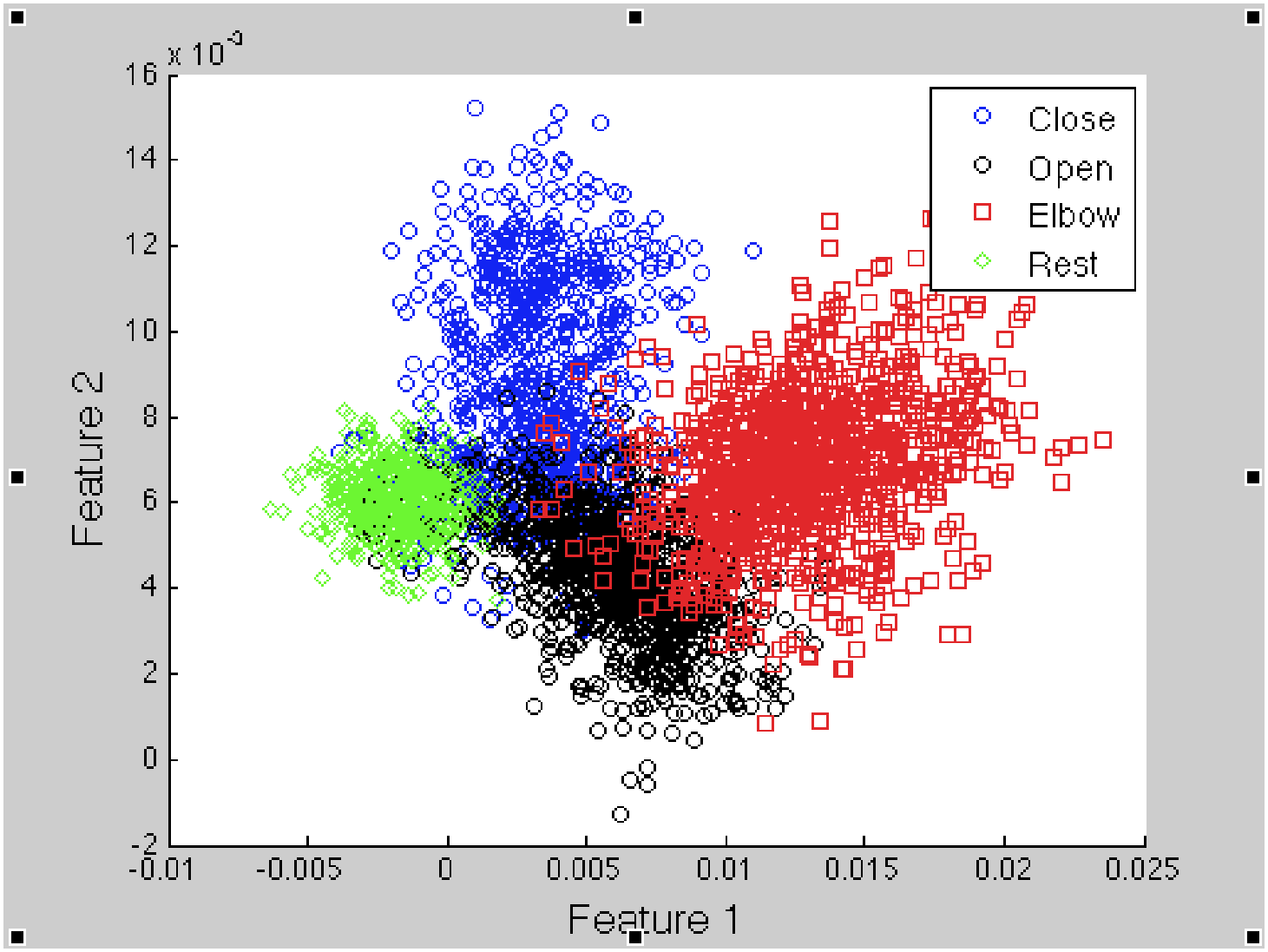


RESULTS




Elbow Extension
Elbow Flexion
Channels
Time
0
5
10
15
20
25
30
0.025
0.02
0.015
0.01
0.005

Hotspots: case study



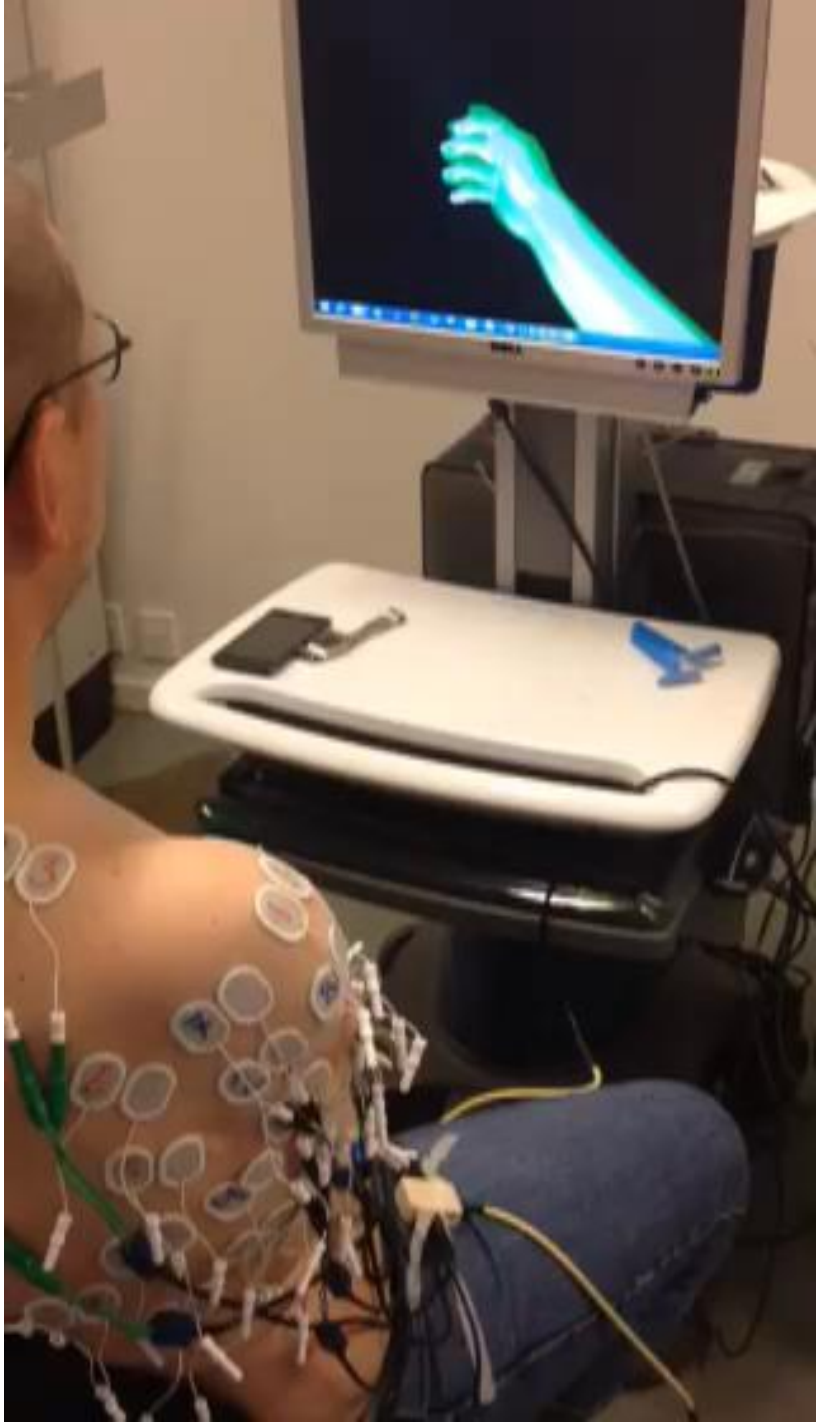
The Target Achievement Control (TAC) Test

Wrist supination/pronation

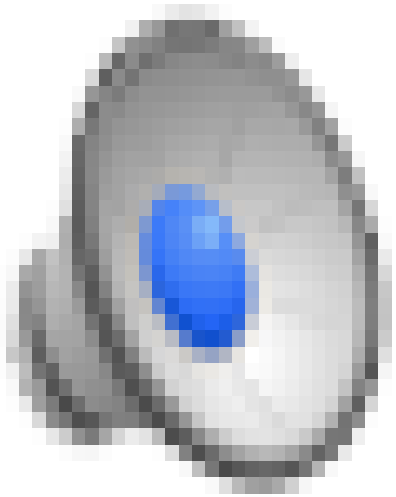
Elbow flexion/extension

From 32 to 8 best channels

TAC test		
Movement	Completion Rate (%)	Completion Time (s)
EF	100	4.66
EE	100	3.46
WS	100	4.82
WP	75	5.62
Mean	93.75 ± 12.5	4.64 ± 0.89



Reduced to 2 sites with a real hand



Current challenges

- Good acute performance
- Performance decreases over time
  - Electrode shift, sweat
  - Changes in signal properties
- Not robust outside the laboratory
- *Limited number of multi days (sub-chronic) recordings studies*

Sub-chronic investigations of surface and intramuscular EMG

10 able-bodied subjects

6 amputees

6 bipolar intramuscular wire electrodes implanted for 7 days

6 bipolar surface electrodes (DONING and DOFFING every day)

Ultrasound guided needle insertion
Targeting the supinator muscle

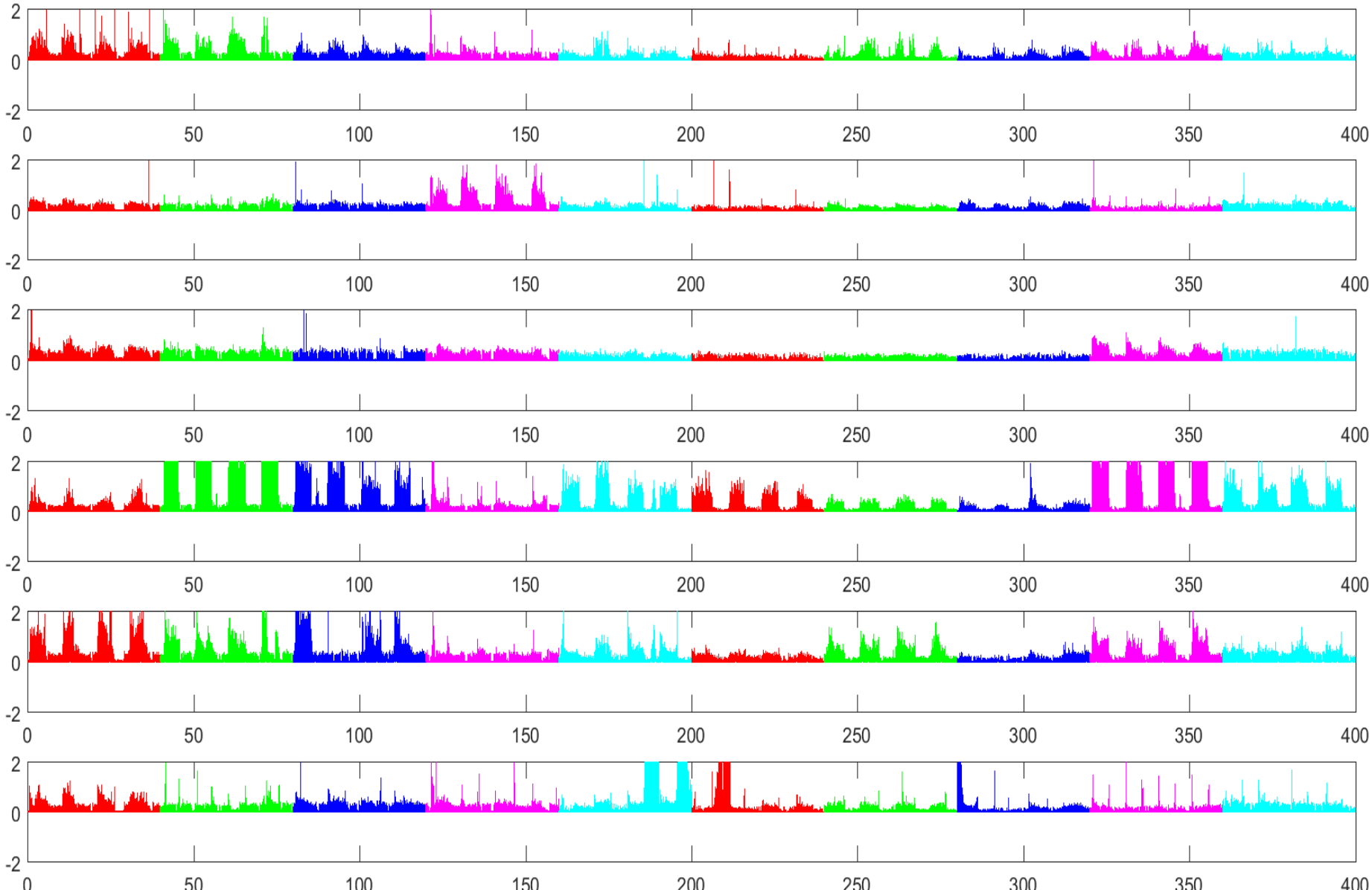
A

B

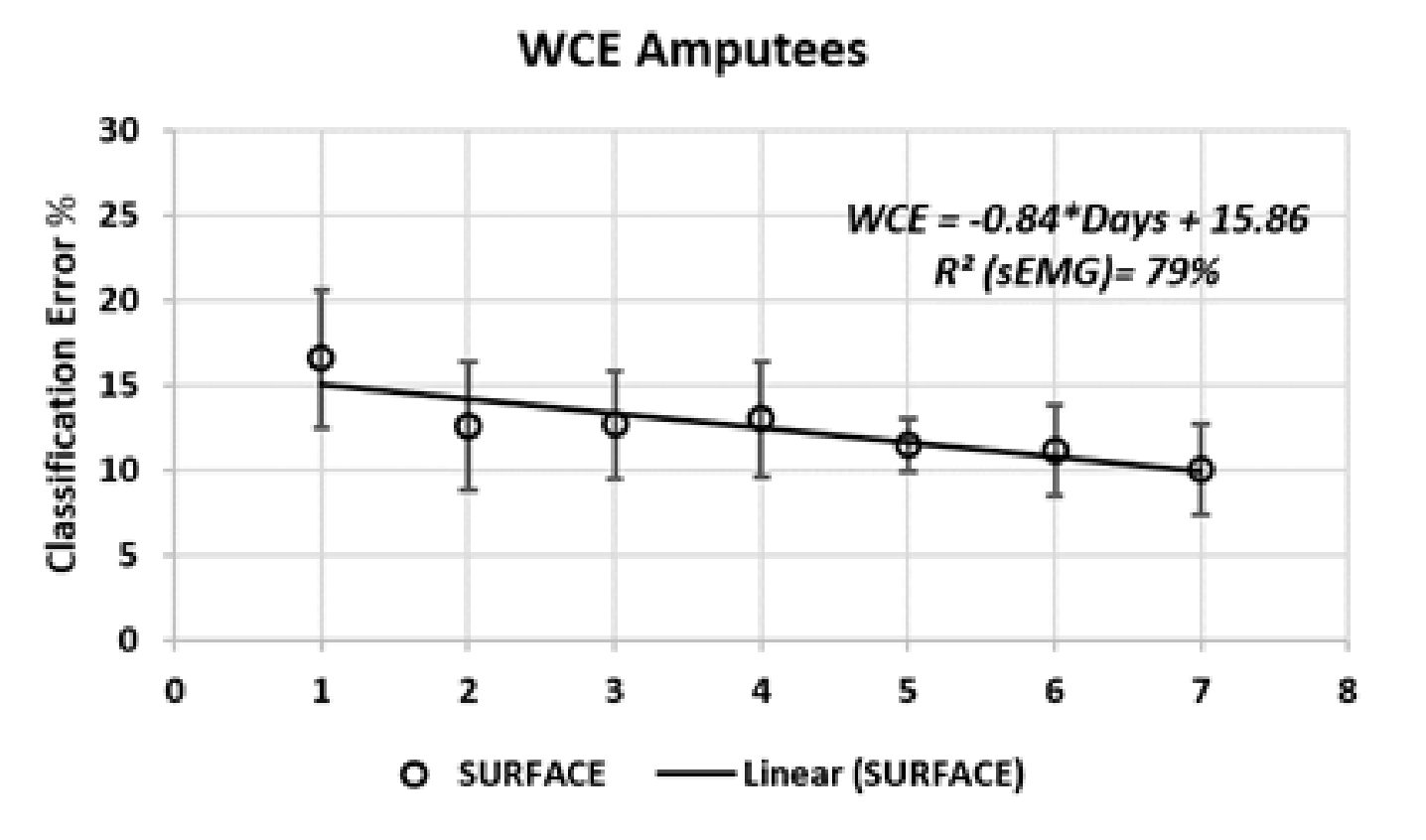
C

8 trials per day
Day 3
Day 2
Day 1

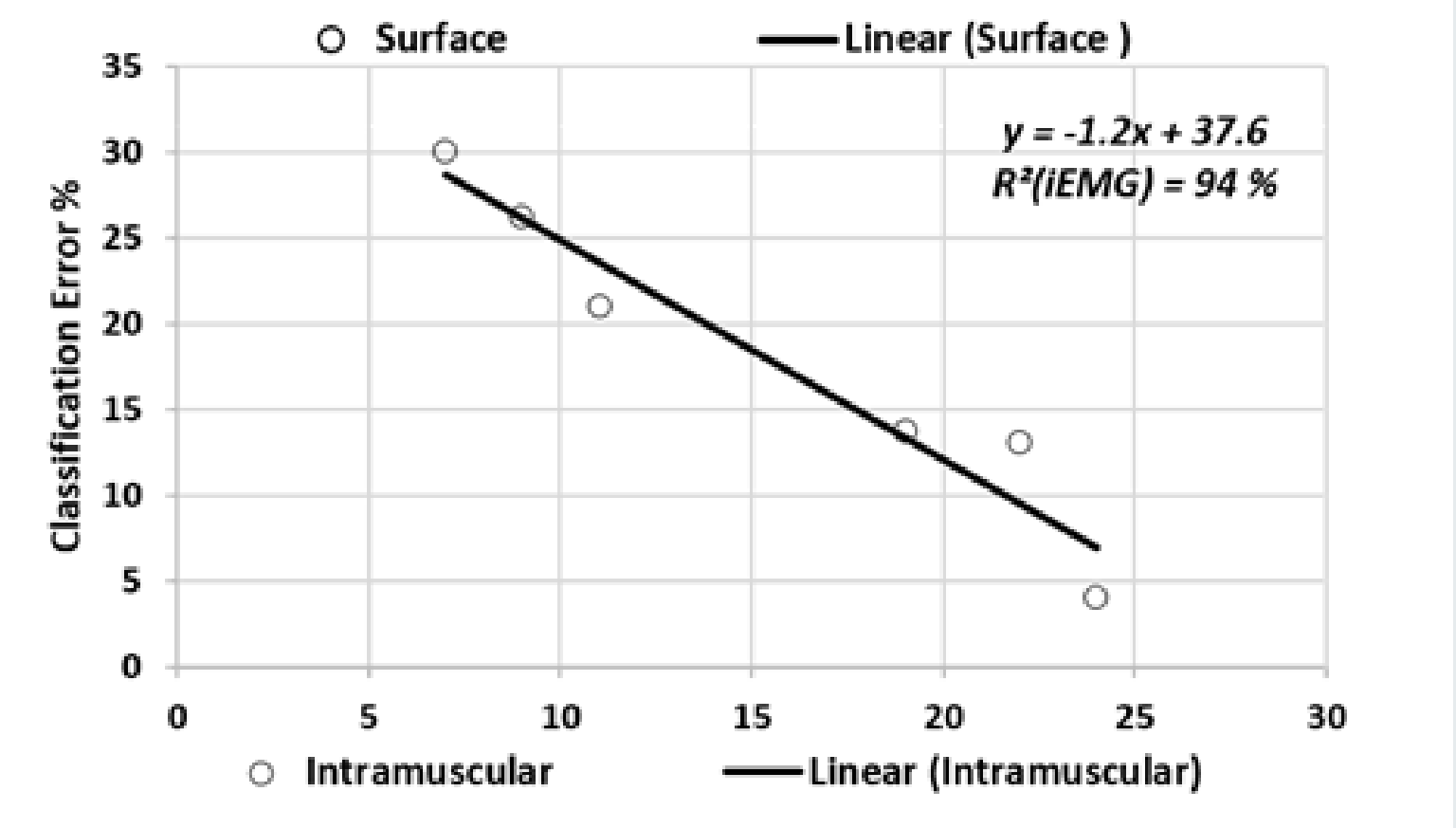
Movement variability



Better performance with time

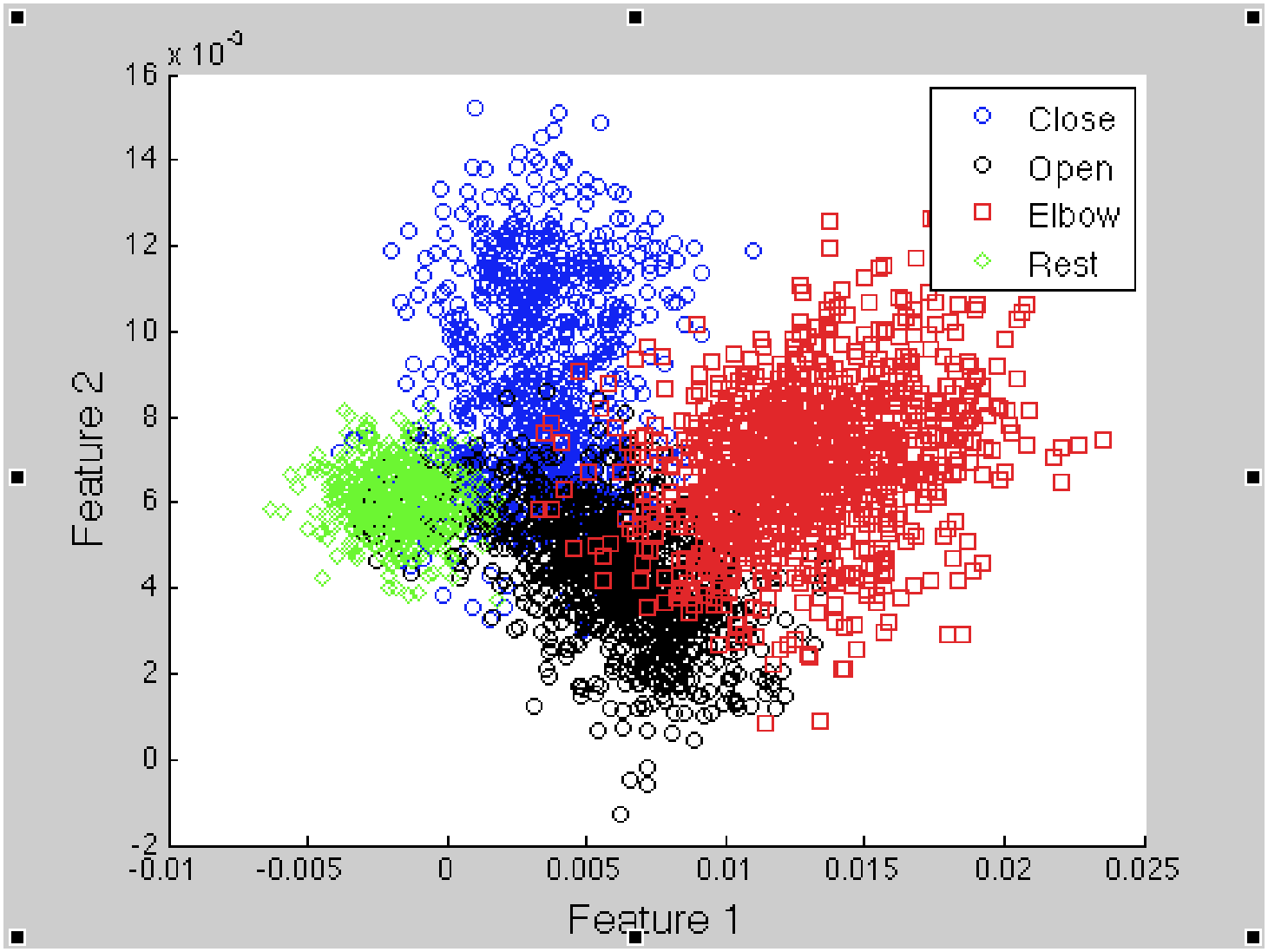


Amputation size

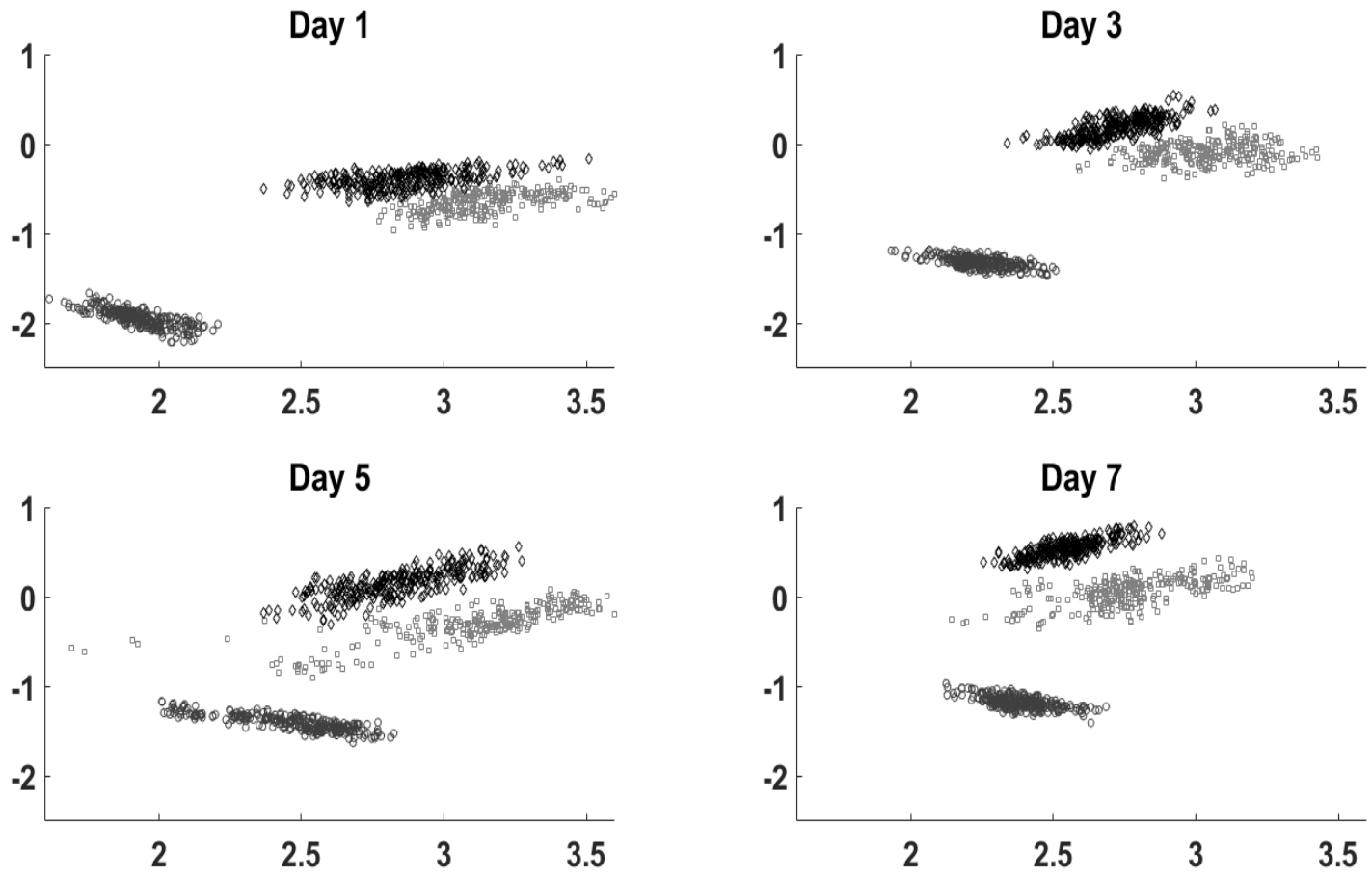


Short Stump vs. Long Stump

Movement distribution



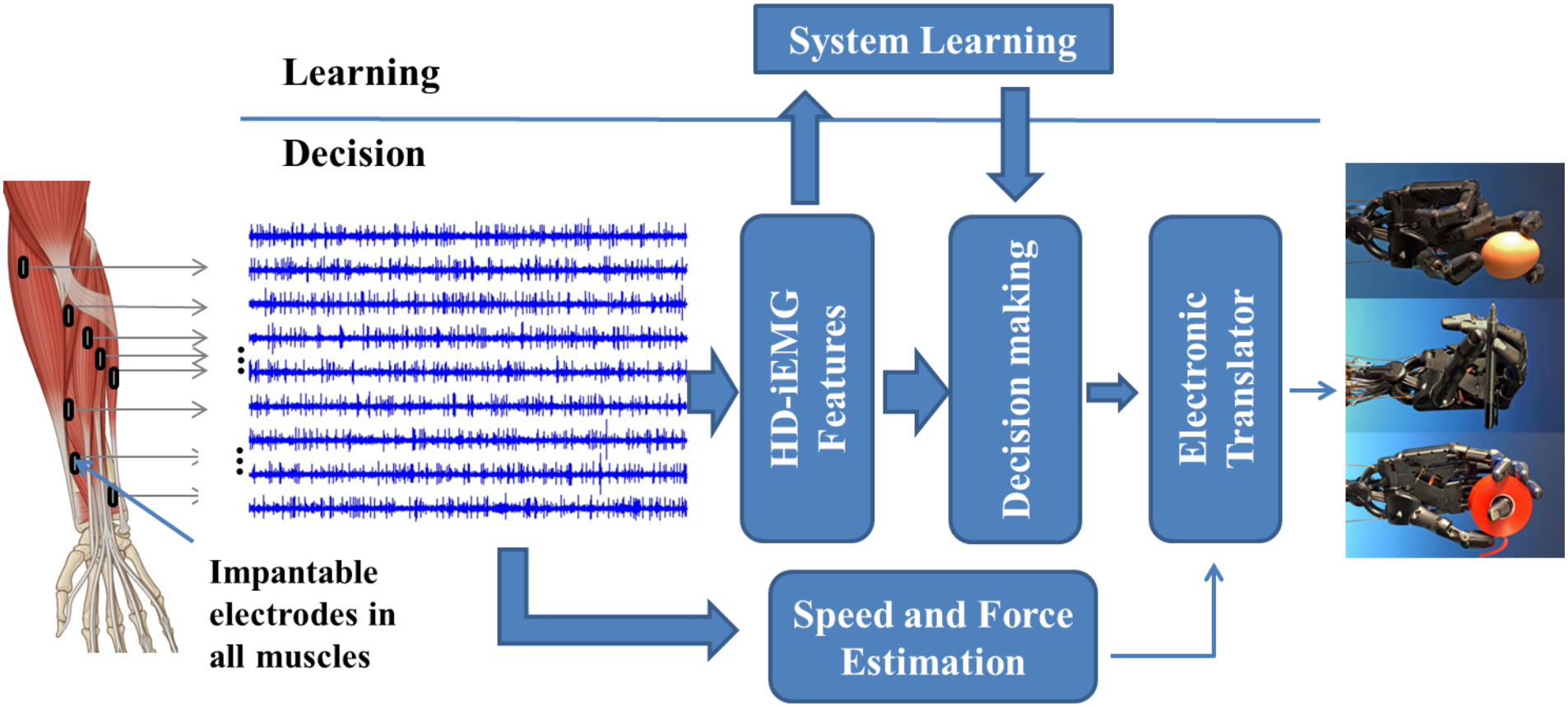
Movement distribution over time



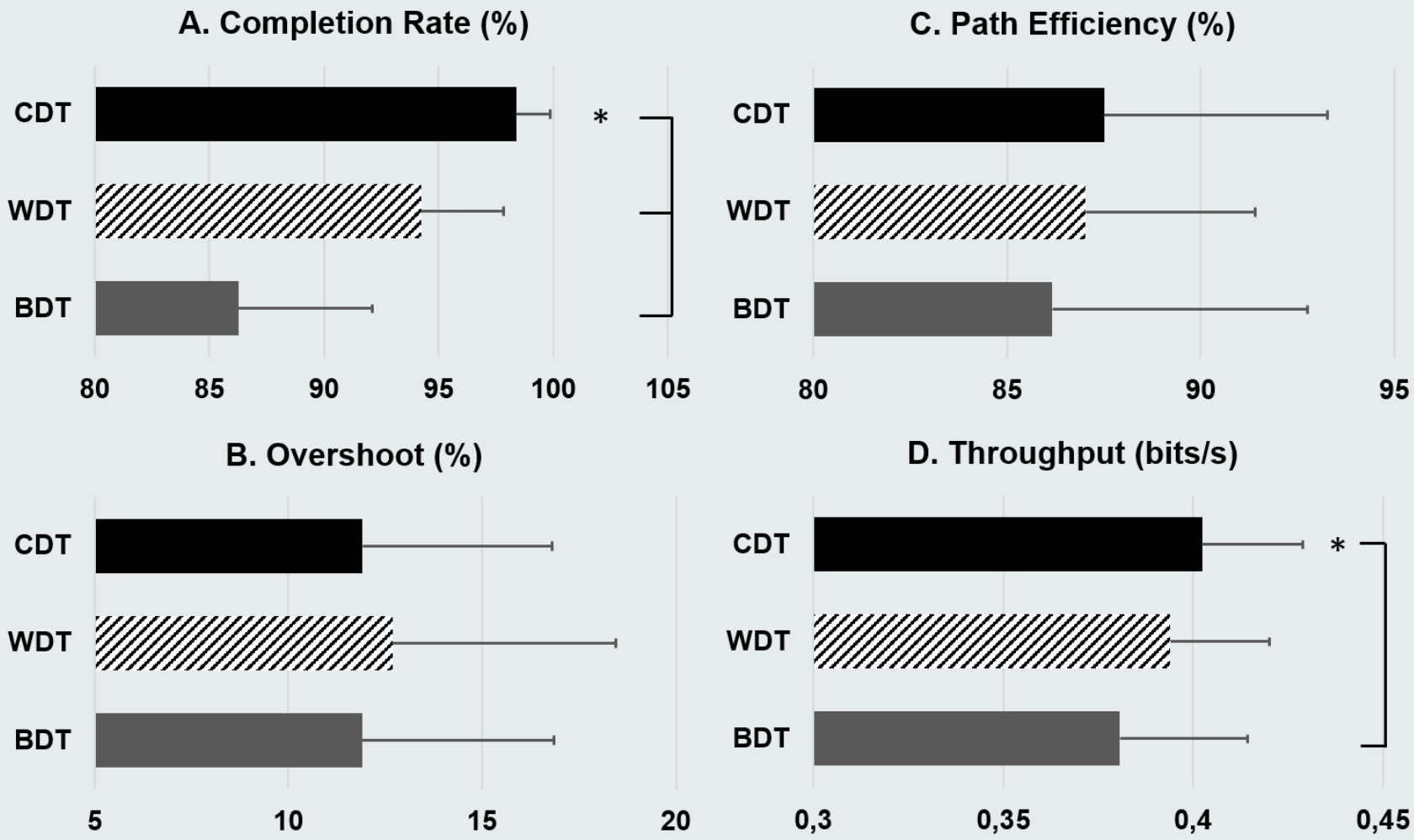
Possible solutions

- **The brain uses many muscles to control the hand**
- **The brain learns**
  - With time
  - Lot of experience

Can we mimic that learning process?


System Learning
Learning
Decision
HD-iEMG Features
Decision making
Electronic Translator
Impantable electrodes in all muscles
Speed and Force Estimation

CDT: combined data



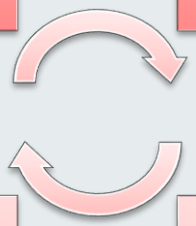
Conclusion

- People with limb amputation
- Regain functions

Research Motivation

Status

- Advanced mechanics
- Clinically: 2 sites surface control,TMR
- Laboratory: Multiple DOFs



Current research focus

- Deep learning
- Maximum information
- ***FEEDBACK***

Current challenges:

- Limited understand of BRAINISH
- Lack of Robustness

Basic Principles

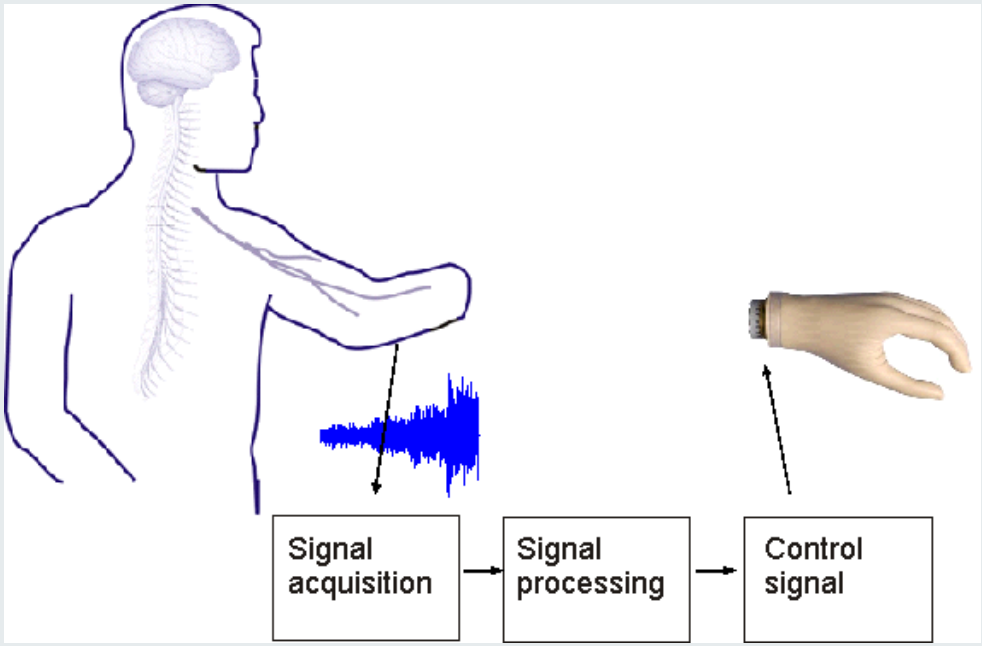
Electromyogram (Electric signals from muscles)

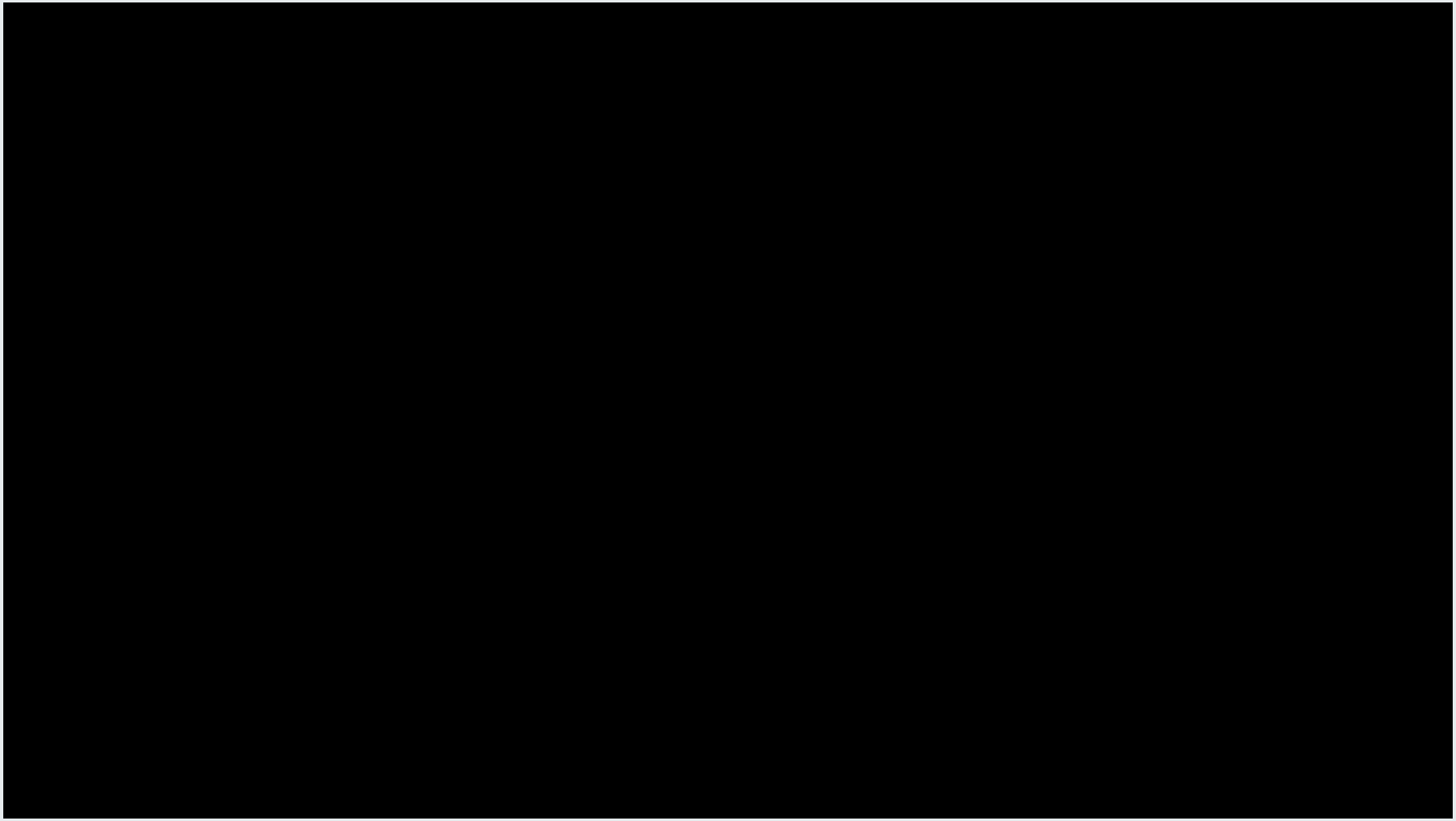
Process

Control

Commercial systems

Myoelectric control



Stable => Functional => Robust

Real-life story