Brain-Robot Interaction: Inferring Subjective Neuroprosthesis Behaviour from Human EEG

A. Billard
I. Batzianoulis
S. Wei
A. Saurav

J.d.R. Millán
F. Iwane
R. Chavarriaga

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Residual Motor Capabilities May not Suffice to Control Robots

Small accuracy in wrist rotation and grasping

Compensation with moving the torso

Mechanical motion and discomfort

Rejection of the device
Current BMIs not Suitable for Long-Term Use

Need for recalibration
Long training
Not dexterous control

Implanted electrodes
Hochberg et al., 2012

Non-Invasive BMIs
Leeb et al. 2010
Hybrid brain-machine interfaces for natural neuroprosthetic control

Reliable, precise control of neuroprostheses for long periods of time without recalibration

Naturalness of prosthetic control

Endow prosthesis with learning capabilities

*Inverse Reinforcement Learning* +
*Error-related Brain Potentials*
Inverse Reinforcement Learning (IRL)

Exploit demonstrations from experts to infer:

1. Optimal control policy
2. Reward function

Who are our experts? The (disabled) users themselves!
Inverse Reinforcement Learning

- Autonomous obstacle avoidance
- Introduced demonstrations
- EEG decoder output
- Inverse Reinforcement Learning
- Desired trajectory
Error-related Brain Potentials (ErrP)

Main Challenge:
Detection of ErrP during continuous motion

[Graph showing electrophysiological data with labels and markers for different time points and conditions at FCz location]
IRL + ErrP: Experimental Set-Up & Results (I)

Evolution of the reward function when increasing the number of demos

Grey dashed lines: trajectory generated by IRL

Red, green and black lines: successive testing trajectories
IRL + ErrP: Results (II)

Number of corrections and corrections before and after training IRL. The number of trials varies between N=8 and N=5. The graph shows a significant decrease in corrections after training IRL, with statistical significance indicated by ** and *.
IRL + ErrP: Pick-and-Place Task

Training phase: same task as in Experiment 1
IRL + ErrP: Customization to Individual Preferred Trajectories (1)
IRL + ErrP: Customization to Individual Preferred Trajectories (II)
Summary

Reliable, precise and natural control of neuroprostheses over long periods of time without recalibration

**Overarching goal**

System will continuously improve its performance, based on user’s feedback

Neuroprosthesis learns how to operate based on the individual user’s own preferences

Pave the way to neuroprosthetic systems suitable for long-term, independent use
Outlook

1. Fast and robust intention detection
   Robust fusion of multimodal channels (EEG, EMG, Eye-tracking) according to their temporal characteristics and reliability

2. Validation with subjects with motor disabilities