Real-time robot arm control using motor imaginary movements decoded from EEG signals

Research Practice

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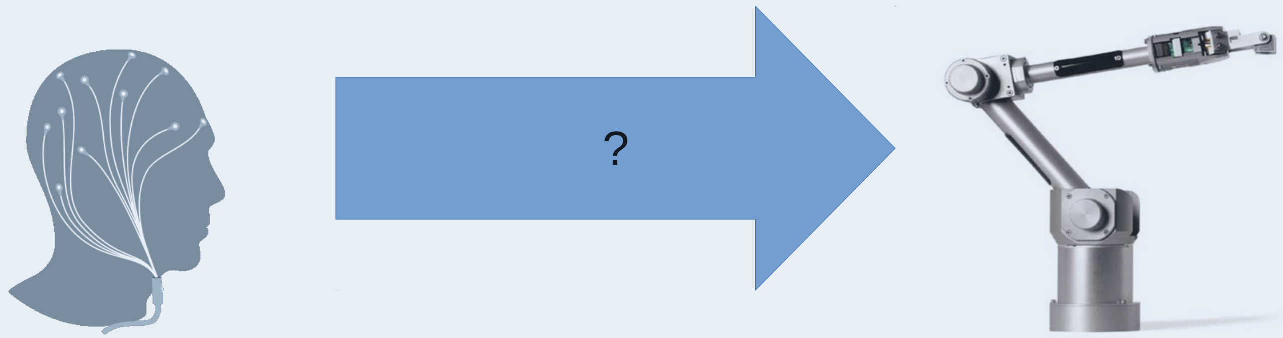
Overview

1) Introduction
2) Experimental Design
3) Results
4) Conclusion

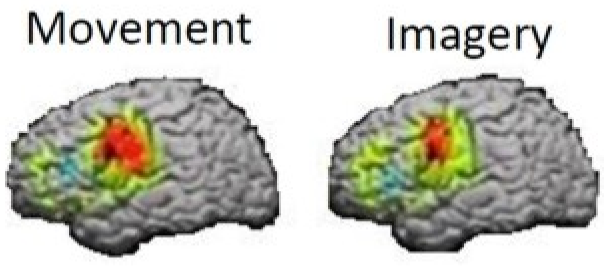
Introduction



How to control a robot arm using nothing but our mind?

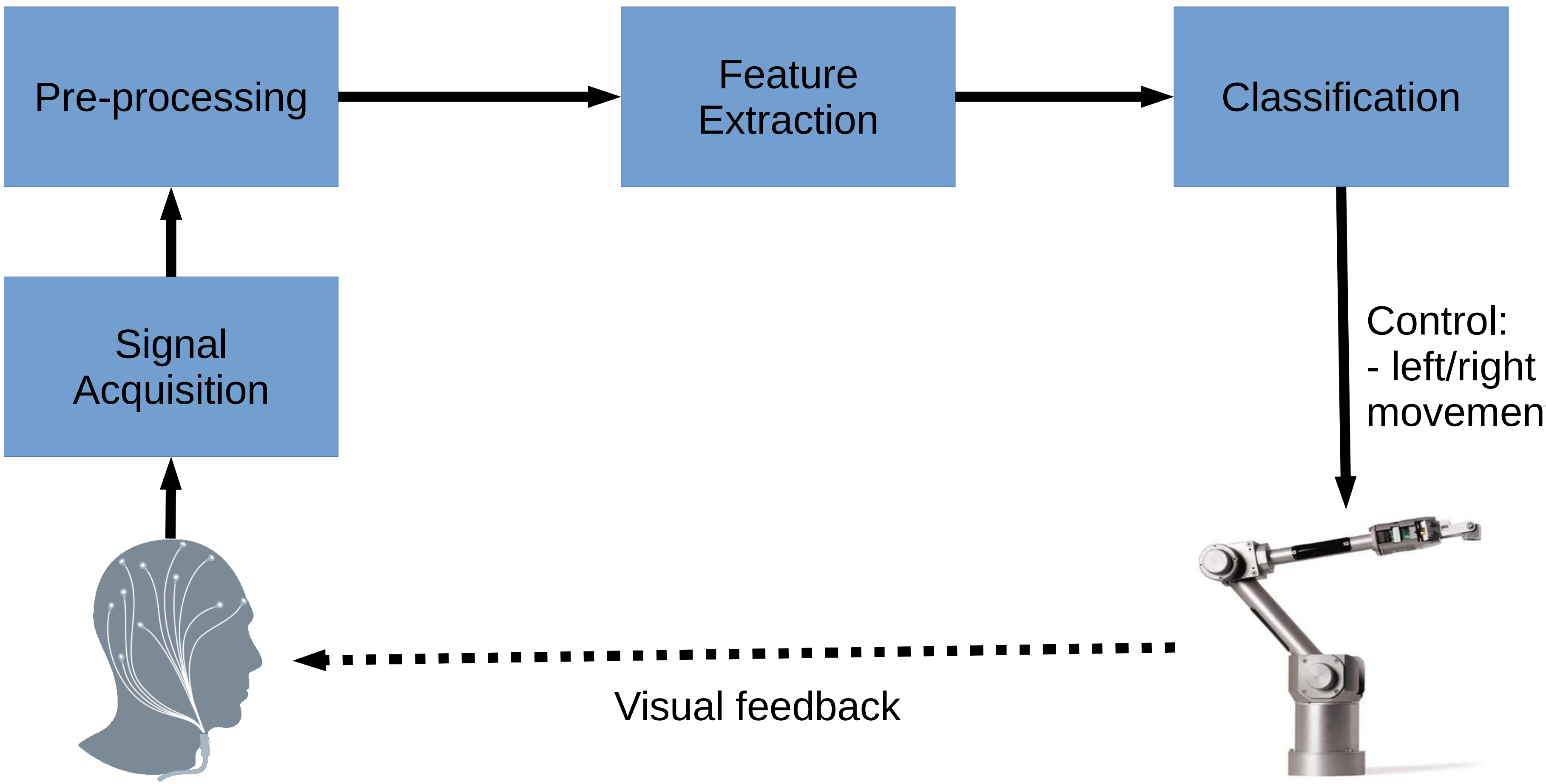
Motor Imagery
Introduction

- Motor Imagery (MI) is the mental rehearsal of physical tasks
- Similar brain areas are activated as in physical execution
- Mainly present in mu rhythm (8-13 Hz) & beta band (14-30 Hz)



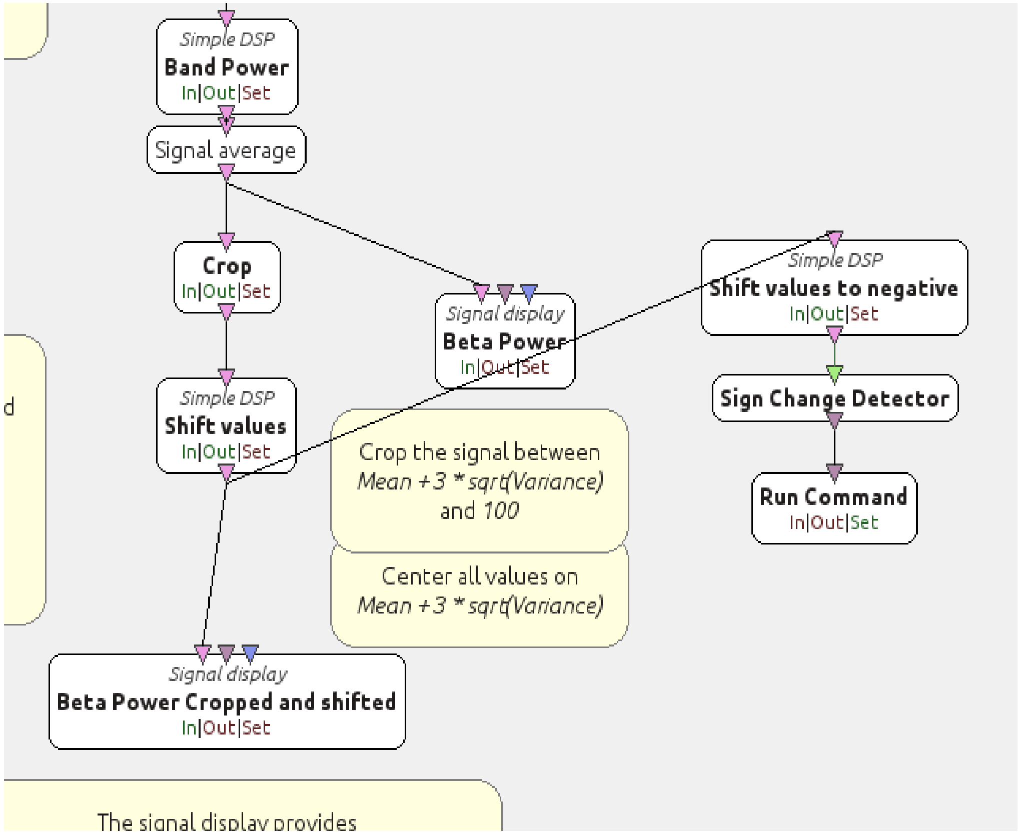
[15]

Full system overview
Introduction



First approach – OpenVibe & Emotiv

Experimental Design

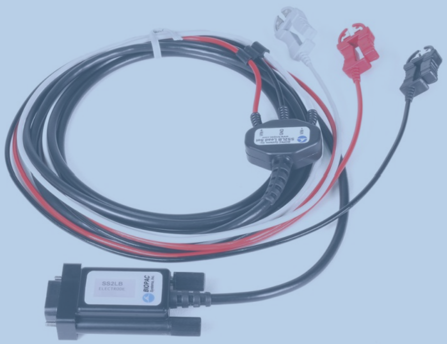


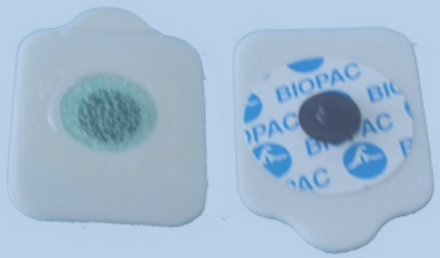
OpenVibe Workflow

Emotiv EPOC+ headset

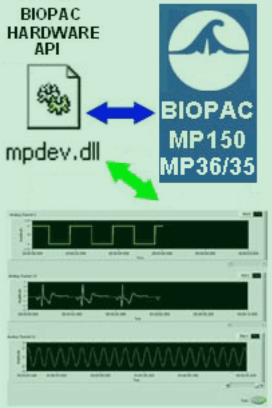
Second Approach – Biopac System

Experimental Design





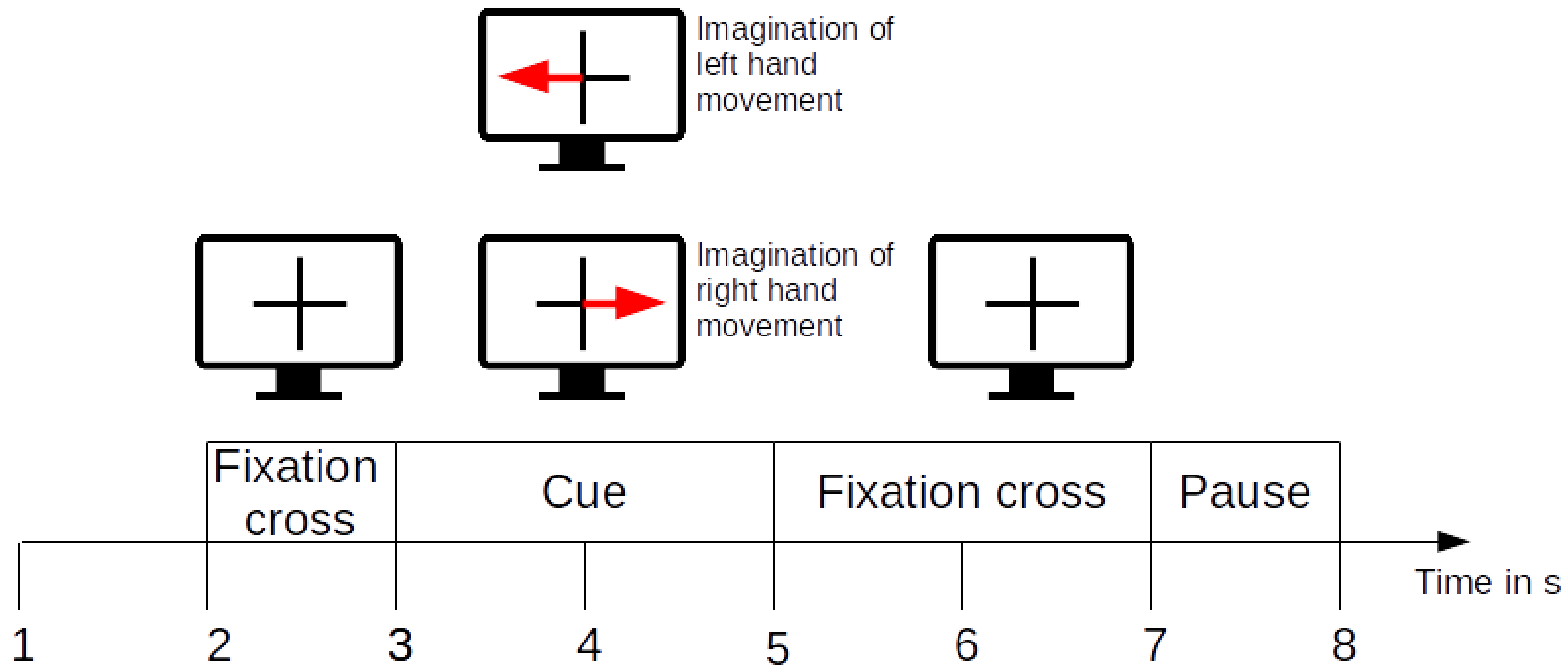
Biopac MP36 Signal Acquisition Device



Biopac Hardware API

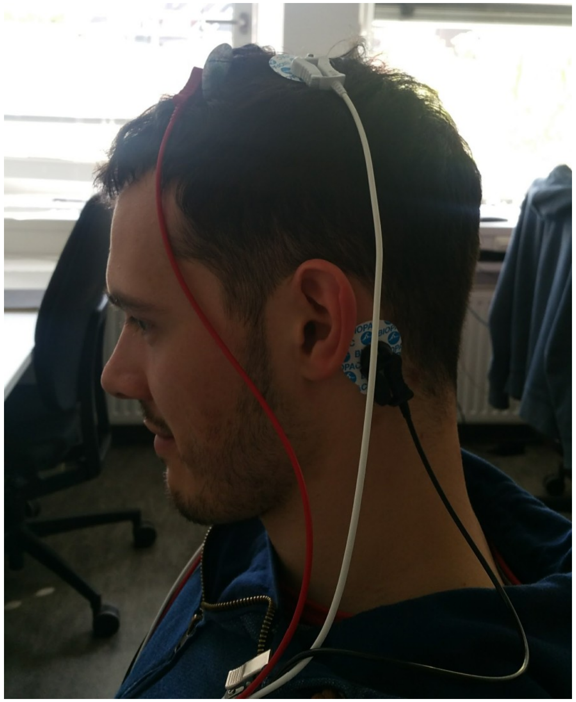
MATLAB

Recording Protocol
Experimental Design

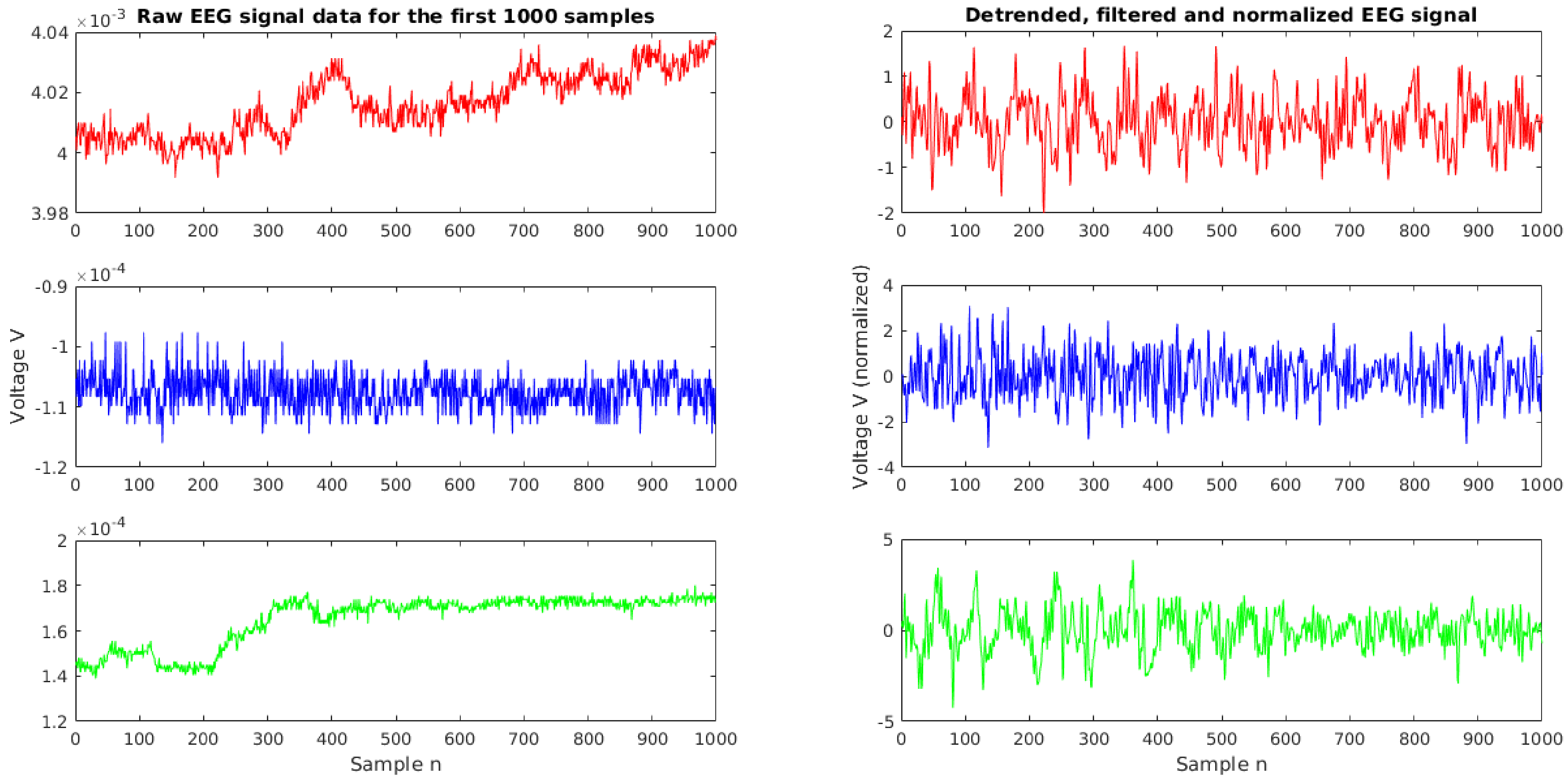


Data Acquisition

Experimental Design



Signal Processing
Experimental Design



Feature Extraction
Experimental Design

- 2000 ms epochs; 500 ms pre-stimulus baseline
- Band power (BP) features
  - 72 frequency bands using overlapping narrow bands in range between 8 and 30 Hz
- Total of 216 BP features
- Principal component analysis (PCA) with 12 coefficients → 12-D feature vector per trial

Classification
Experimental Design

- SVM model `fitcsvm()` from Matlab toolbox „Statistics and Machine Learning“
- Radial basis function (RBF) kernel
- 10-fold cross-validation with `crossval()`
- Misclassification rate with `kfoldLoss()`

Robot Arm Control
Experimental Design

- Python script for communication with SOAP server
  - py.KatanaSoap.KatanaSoap()
  - katana.calibrate()
  - katana.moveMotAndWait(axis, val)
  - katana.closeGripper(), katan.openGripper()
  - ...

Off-line Classification
Results

Recording ID	Number of trials	Accuracy (%)
AS01-11	40	63
AS02-11	40	67
JF02-10	40	63
JF03-10	40	74
JF04-10	40	74
AS02-12	40	**77**
JF02-15	50	66
JF02-16	50	60
JF01-15	50	58
JF01-16	50	60
AS01-16	50	46

On-line Classification
Results

Video

Conclusion

- Simple 2-class BCI
  - Decent off-line accuracy of ~77%
- Unsuitable for on-line applications
  - Signal quality cannot be maintained over longer periods of time (→ electrode design)
  - Discomfort for user
- Possible improvements
  - Try different features: common spatial patterns (CSP), discrete wavelet transform (DWT), dynamic time warping (DWT), …
  - Try other classifiers: Artificial or spiking neural networks (ANNs, SNNs), linear discriminant analysis (LDA), deep neural networks, ...

Thank you for your attention!

Sources

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Questions?