Primitive Shape Imagery Classification from Electroencephalography

Introduction
- BCIs augment traditional interfaces for human-computer interaction and provide alternative communication fields that may enable the physically impaired to work.
- Imagined object / shape classification from electroencephalography (EEG) may lead, for example, to enhanced tools for fields such as engineering, design, and the visual arts.
- Evidence to support such a proposition from non-invasive neuroimaging techniques to date has mainly involved functional magnetic resonance tomography (fMRI) [1] indicating that visual perception and mental imagery show similar brain activity patterns [2] and, although the primary visual cortex has an important role in mental imagery and perception, the occipito-temporal cortex also encodes sensory, semantic and emotional properties during shape imagery [3].
- We investigate if five imagined primitive shapes (sphere, cone, pyramid, cylinder, cube) can be classified from EEG using filter bank common spatial patterns (FBCSP) [4].

Experimental setup
- The analysis performed on two datasets (using the same experimental protocol)
  - Experiment 1: 10 subjects / 1 session
  - Experiment 2: 3 subjects / 3 session
- Each session involved 72 trials / shape: 3 runs, 4 blocks/run, 30 trials/block (total)
- EEG recorded on 30 channels as presented

Methods: Filter Bank Common Spatial Patterns
- Decoding accuracy (DA) was tested for 3 different multi-classifier options
  - Selected method (base on test DA): multiple 2-class classifier based RLDA architecture

Results
- DA peak ~1s after onset of the shape imagery task.
  - DA~20% chance level prior to (-1s) display period.

Topographical analysis (spatial distribution of CSP and MI weights at time of peak accuracy)
- CSP-MI weights show shape-related neural activity in centro-parietal and occipito-temporal cortex.
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  - Spatial pattern of CSP-MI weights show similar distribution for mental imagery of different shapes.

Motor imagery task (a comparison to shape imagery)
- High spatial separability of CSP-MI weights detected in SMA & M1 for different motor-imagery tasks
  - This result explains the high level of DA achieved for motor-imagery task classification during our method validation process (4-class DAmean~75%, DAmax~90%, chance level 25%).

Result summary: We achieved significantly higher DA for imagined shape classification as the chance level prior to the display period (5-class DAmax~28%, DAmean~37%, chance level 20%) despite imagery of different shapes activating similar cortical areas. CSP-MI weights indicated task-related neural activity in occipito-temporal & parietal cortex in low frequency (delta & theta) bands.

Significance
- Only the second study of shape imagery classification from EEG [5].
- Multi-session online experiment with real-time feedback of task performance may improved DA.

References

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