On the Use of Brain-Computer Interfaces Outside Scientific Laboratories: Toward an Application in Domotic Environments

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Workshop on BMI for Space Applications

Noordwijk (The Netherlands), 30 November 2009
“Brain–computer interfaces (BCI’s) give their users communication and control channels that do not depend on the brain’s normal output channels of peripheral nerves and muscles.”

“A BCI changes the electrophysiological signals from mere reflections of CNS activity into the intended product of the activity: messages and commands that act on the world”

Wolpaw et al. 2002, clinph
Goal of Brain-Computer Interface research is to provide:

- A new control option
  (to people with severe motor disabilities)

- Functions that normal muscular control can’t address
  (to able-bodied people)
The model of BCI

appropriate feature extraction

Modification of Brain Signals

Psychological Effort (Intention)

Signal Features

Classification Of Intent

appropriate feedback strategy

user training

computer training

Environment

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ESA BMI Workshop - Nov 30, 2009
The model of BCI (2)
Detection of brain activity

Detection of activity in the CNS
- Electrocorticography (ECoG), Intracortical potentials (microelectrodes), Depth Electrodes (SEEG), …
- Electroencephalography (EEG), Magnetoencephalography (MEG), Functional Magnetic Resonance Imaging (fMRI), Near Infrared Spectroscopy (NIRS), …
EEG features for BCIs

Detection of sensorimotor rhythms modulation

Detection of P300

Detection of Slow Cortical Potentials

Detection of steady-state (V)EPs
Mu-Rhythm for BCI

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Cursor control

- **Left vs. Right hand**
  \[ \Delta y = S^\alpha_{C3} - S^\alpha_{C4} \]

- **Upper vs. Lower limb**
  \[ \Delta y = S^\alpha_{Cz} - \frac{1}{2} \left( S^\alpha_{C3} + S^\alpha_{C4} \right) \]
The P300 is an event-related potential, dominating at parietal electrode sites.

P300 follows unexpected sensory stimuli or stimuli that provide task related information.

P300 speller

From Selllers & Donchin 2006, clinph
Domotic applications

User
(Brain) Interface
(Smart) Controller
Actuators
Beyond a BCI-centric approach

Cincotti et al 2008, BRB
SMR control of a home environment

“ASPICE” Project
(Italian Telethon Foundation)
P300 control of a home environment

“SM4All” Project
(FP7-ICT STREP)
P300 control of a home environment

Domotic Control using Brain Computer Interface (P300 based)

“SM4All” Project (FP7-ICT STREP)
Possible improvements

Signal processing: Neuroelectrical imaging
HCI: Non-visual feedback/stimulation

... Asynchronous control
Reduce symbolism
Neuroelectrical Source Imaging (2)

Subject 2

RAW

CAR

Laplacian

Source Imaging

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SMR Vibrotactile feedback (1)

Cincotti et al 2007, CIN
SMR Vibrotactile feedback (2)

- SMR patterns are comparable
- Control performance are slightly reduced
SMR Vibrotactile Feedback

“MAIA” Project
(FP5 – STREP)
Multimodal stimulation for a P300-BCI

Aloise et al 2007, IJBEM

Statistics
New challenges

- Targeted non muscular communication devices
- Non-invasive neuroprosthetics
- Non-deterministic applications (entertainment)
- Monitoring/fostering cortical plasticity

- Hybridization with muscular channels
- Asynchronous recognition of mental states (SMR, MRP, P300)
- Merging with the wider HCI fields
- Improved sensors: dry electrodes
- Standardization
- Wearable/Embedded platforms
- Evaluation metrics
- Ethics
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