Brain Computer Interface for communication and control

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In the classical Star Wars third movie (the return of Jedi) Darth Vader reveals a connection between his neural system and the computer.

Today, such high level of integration between man and machine seems really yet too far from the common practice.
Overview of the presentation

- Definition of a Brain Computer Interface
- Principal neurophysiological signals that can be used to do the job
- The most active research groups in the BCI field and their achievements
- Future trends

Nicolelis, Nature 200
Brain-Computer communication through EEG

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, 2002

Feedback and biological adaptation

Acquisition or estimation of the cortical activity

Activation in the real world

Processing and classification of cortical signals

Actuation in the real world

Wolpaw, 2002

Nicolelis, Nature 2001
The most downloaded paper from Clinical Neurophysiology

Invited review

Brain–computer interfaces for communication and control

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Accepted 2 March 2002
Variations of EEG waves are correlated with some mental states:

- 8-12 Hertz, alpha EEG waves
- 8-12 Hertz, mu EEG waves
Movement-related thoughts elicited specific cortical patterns

Neuroscientific studies with fMRI have demonstrated that motor and parietal areas are involved in the imagination of the limb movements.

Several EEG studies have been also demonstrated that imagined movements elicited desynchronization patterns different for right and left movement imaginations.
A closer look into the brain dynamics underlying the movement preparation and execution

MRPs Right finger movement alpha ERD

From -1 before (movie start) to +0.1 sec post-movement

Where: centro-parietal scalp area
On the use of neurophysiological signals to control devices

- Time-dependent features
  - Times series values
- Frequency dependent features
  - EEG, EMG, EOG

- Quality of sensors
  - SNR (EMG >>10, EEG ≈ 1)

Feature extraction

Pattern Recognition
- LDA, MDA
- Non linear classifier

Actuators

EEG, EMG, EOG
Present-days BCIs

A SLOW CORTICAL POTENTIALS

B P300 EVOKED POTENTIAL

C SENSORIMOTOR RHYTHMS

D CORTICAL NEURONAL ACTIVITY
Threshold classifiers for the Brain Computer Interface (Tübingen)

Institute of Medical Psychology and Behavioural Neurobiology
Department chair: Prof. Niels Birbaumer

Eberhard Karls Universität Tübingen

Dr. Andrea Kübler - biologist
Nicola Neumann - psychologist
Slavica Coric - assistant
Dr. Thilo Hinterberger - physicist
Dr. Jochen Kaiser - psychologist
Dr. Boris Kotchoubey - psychologist, physician
Dr. Jouri Perelmouter - mathematician
Patient HPS using the Thought Translation Device

A SLOW CORTICAL POTENTIALS

[Graph showing slow cortical potentials with peaks and troughs over time]
Present-days BCIs

A. Slow Cortical Potentials

B. P300 Evoked Potential

C. Sensorimotor Rhythms

D. Cortical Neuronal Activity
Unbalance of ERD for imagined left and right movements
EEG patterns related to cognitive tasks

Power spectrum increase/decrease of EEG data recorded when subject imagines or performs a movement of his middle finger.

Brain Computer Interfaces at the Graz University

Prof. Gert Pfurtscheller

Mu-rhythms pattern recognition by linear and non-linear classifiers
The Adaptive Brain Interface

Maria Grazia Marciani
Donatella Mattia
Febo Cincotti
Fabio Babiloni

José del R. Millán
Josep Mouriño
Marco Franzè

Markus Varsta
Jukka Heikkonen
Kimmo Kaski

Fabio Topani
Adriano Palenga
Fabrizio Grassi

HELSINKI UNIVERSITY OF TECHNOLOGY

FASE Sistemi Srl
Brain-operated Virtual Keyboard

ADAPTIVE BRAIN INTERFACES
A game application
Adaptive Brain Interfaces (ABI)

The Motivation

In today's fast paced world, information and communication technologies are dramatically transforming our society. Access to new emerging technologies can be taken for granted. Unfortunately, not everyone can enjoy their benefits on equal terms. People with severe physical disabilities are practically excluded. But, what if they could communicate their wishes or control electronic appliances merely by thinking? This is promise of the ABI project (http://sta.jrc.it/abi) that aims at augmenting human capabilities by enabling people to interact with computers through conscious control of their thoughts after a short training period.
Present-days BCIs

A. SLOW CORTICAL POTENTIALS

B. P300 EVOKED POTENTIAL

C. SENSORIMOTOR RHYTHMS

D. CORTICAL NEURONAL ACTIVITY
Spelling device (2.25)
Aid screen
P300 spelling device
BCI controlled by estimated cortical activity
Future trends: increase awareness of controlled devices

- BCI is a slow communication channel
  - Best performance with virtual keyboard: 3 characters per minute

- Need for “smart” devices, e.g.:
  - T9 programs for SMS on cellular phones
  - Trajectory aware wheelchairs or robotic arms
EEG Based BCI in rehabilitation

Focus: degree of Autonomy
- Partially restoring the abilities, mostly using alternative strategies
- Communication aid -> Controlling device

Focus: degree of Functional Recovery
- Tuning of the rehabilitation actions to maximize level of recovery
- Cortical plasticity -> Rehabilitation device
Future trends

- Identification of those signals, whether evoked potentials, spontaneous rhythms, or neuronal firing rates, best able to control independent of activity in conventional motor output pathways;
- Development of training methods for helping users to gain and maintain that control;
- Delineation of the best algorithms for translating these signals into device commands;
- Identification and elimination of artifacts such as electromyographic and electro-oculographic activity;
- Adoption of precise and objective procedures for evaluating BCI performance;
- Identification of appropriate BCI applications and appropriate matching of applications and users;
- Attention to factors that affect user acceptance of augmentative technology, including ease of use, cosmesis, and provision of those communication and control capacities that are most important to the user.