RECENT BREAKTHROUGHS IN BRAIN-COMPUTER INTERFACE

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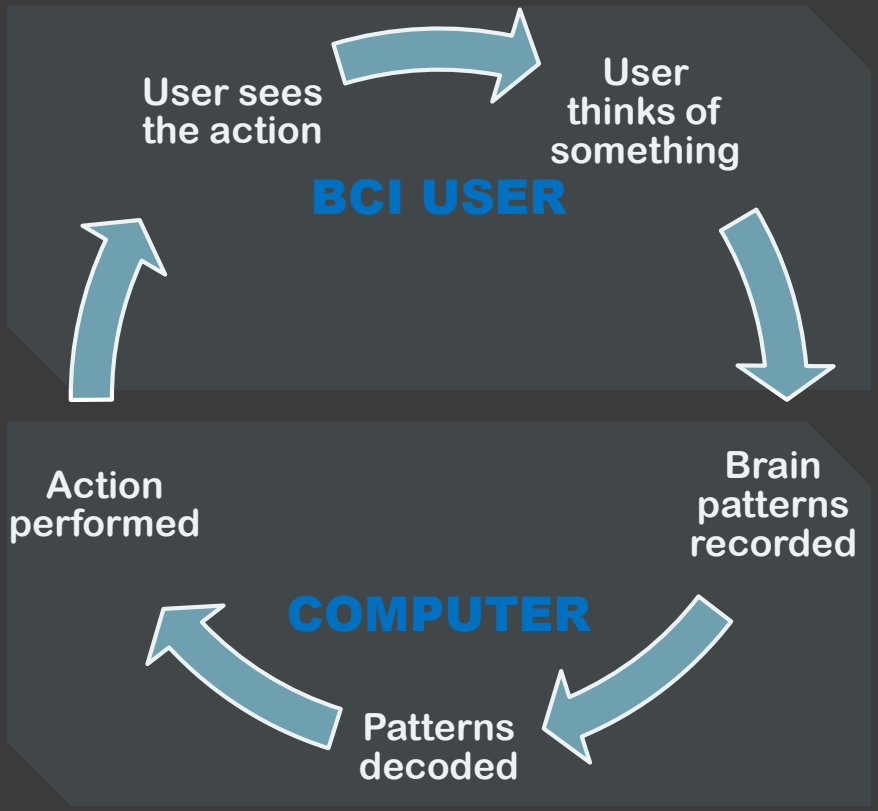
Overview

- Introduction to BCI
  - What is BCI
  - How does it work
  - Computer training & classifier design
  - Transfer rate
- Projects
  - P300 Speller
  - VR Walking Avatar
  - Other devices

What is BCI and what can it do?

- Brain computer interface (BCI) is a direct communication pathway between human brain and a computer device.
- BCI bypasses normal motor pathway and directly controls output devices
  - Text-to-speech
  - Wheelchair
  - Robotic arm, etc.
- Often used for restoring lost bodily functions

How does BCI work?

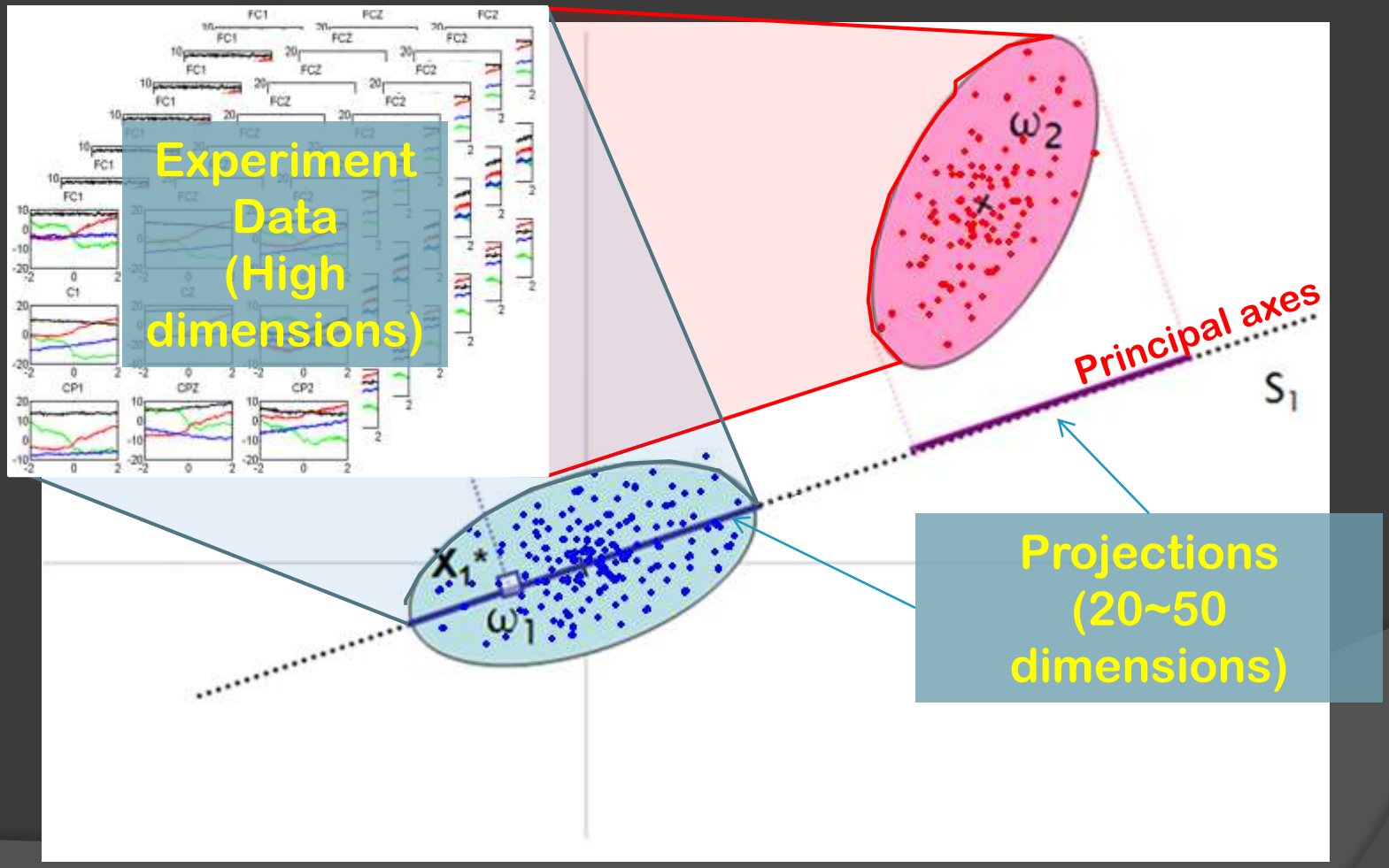


Electroencephalography (EEG)-based brain-computer interface.

Discovering new useful patterns

- BCI relies on consistent mental patterns
  - Where and when
  - Computer training
    - 100 repeated trials per task (200 total)
  - User training

Classwise principal component analysis (cPCA)

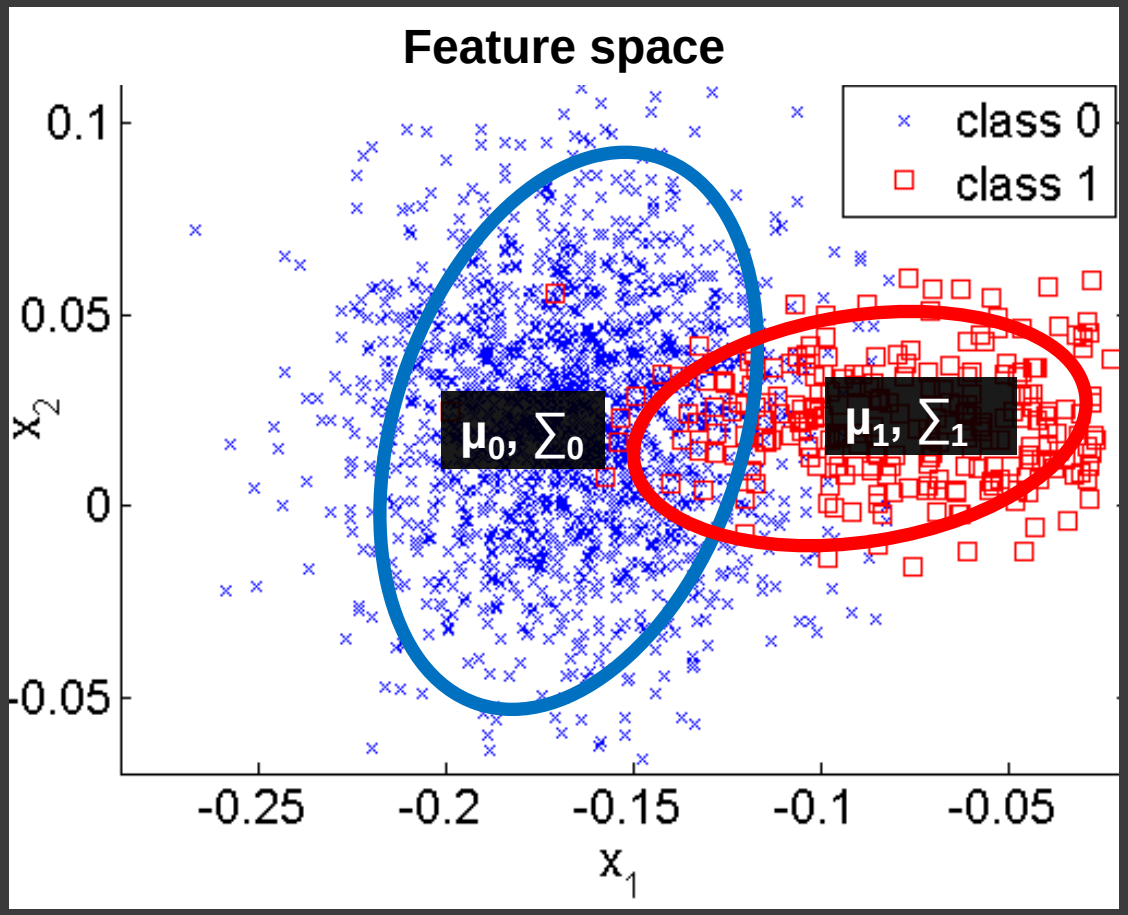


K. Das, S. Osechinskiy, Z. Nenadic. *Conf Proc IEEE Eng Med Biol Soc, (2007)* 6520-6523

Discriminant analysis

- Finds combinations of features that best separate the classes
- Brings down to 1 – 3 dimensions
- Linear Discriminant Analysis (LDA)
- Information Discriminant Analysis (IDA)
  - Das K & Nenadic Z. Approximate information discriminant analysis: A computationally simple heteroscedastic feature extraction technique. Pattern Recogn (2008) 41: pp. 1565-1574.

Bayes Classifier



$$p(\omega_i|D) = \frac{p(D|\omega_i)p(\omega_i)}{p(D)} = \frac{N(\mu_i, \Sigma_i, D)p(\omega_i)}{\sum_i N(\mu_i, \Sigma_i, D)p(\omega_i)}$$

Class decision = $\max_i(p(\omega_i|D))$

Nenadic Lab, unpublished work (2009)

Information transfer rate (ITR)

- **How fast information is communicated.**

$$\mathrm{ITR} = \frac{N_c}{T} \log_2 |\mathcal{A}|$$

Nc = Number of “characters”
T = Total time taken
A = Degrees of freedom per character

- Some comparisons:

Input method	Words per minute	Bits per second
Professional typist[1]	50 – 95	23 - 45
Average computer user[2]	33	15.7
Brain computer interface[3,4]	0.46 – 2.63	0.22 – 1.25

[1]Brown CM (1988). Human-computer interface design guidelines. Norwood, NJ: Ablex Publishing.
[2]Karat CM, Halverson C, Horn D, and Karat J (1999). Patterns of entry and correction in large vocabulary continuous speech recognition systems, CHI 99 Conf Proc, 568–575.
[3]Wolpaw JR and McFarland DJ (2004). Control of a two-dimensional movement signal by a noninvasive brain-computer interface in humans. PNAS U S A, 101(51):17849–17854, Dec 2004.
[4]Krusienski DJ, Sellers EW, McFarland DJ, Vaughan TM, and Wolpaw JR (2008). Toward enhanced P300 speller performance. J Neurosci Met, 167(1):15–21, Jan 2008.

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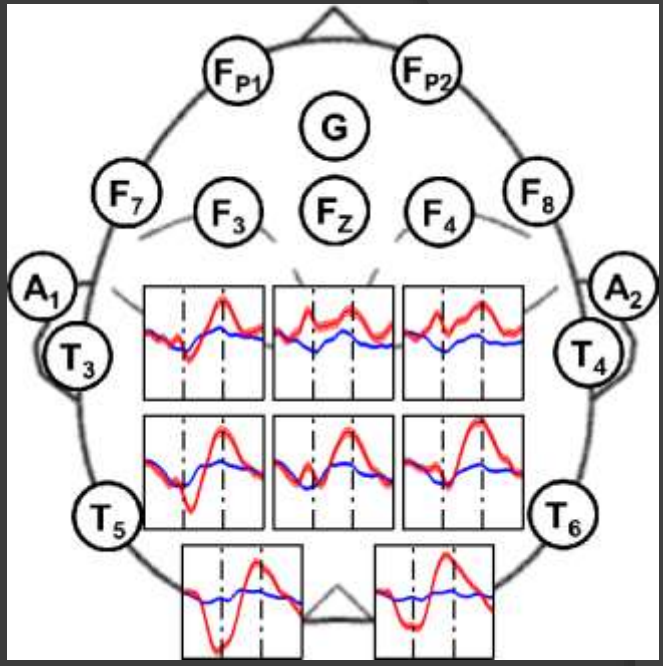
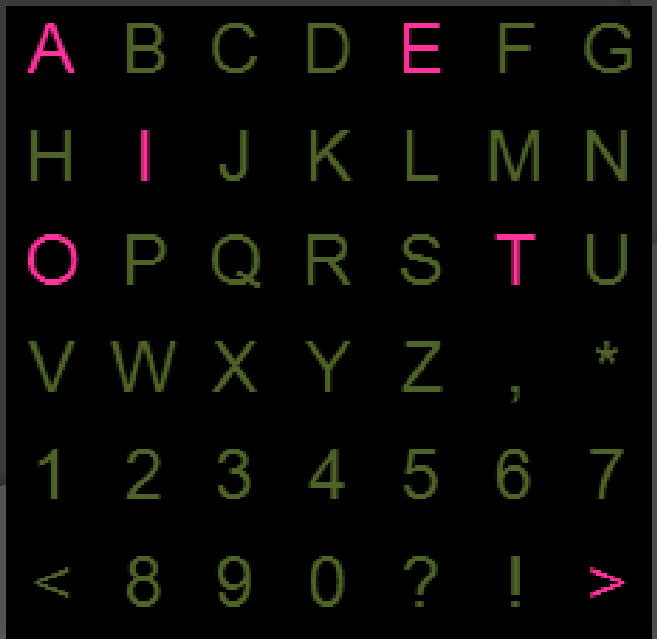
P300 Speller

- Special brain signals (oddball signal) are observed when a person sees a rare object of interest.
- In this case, the objects are letters and digits on the computer screen.





A B C D E F G

H I J K L M N

O P Q R S T U

V W X Y Z , .

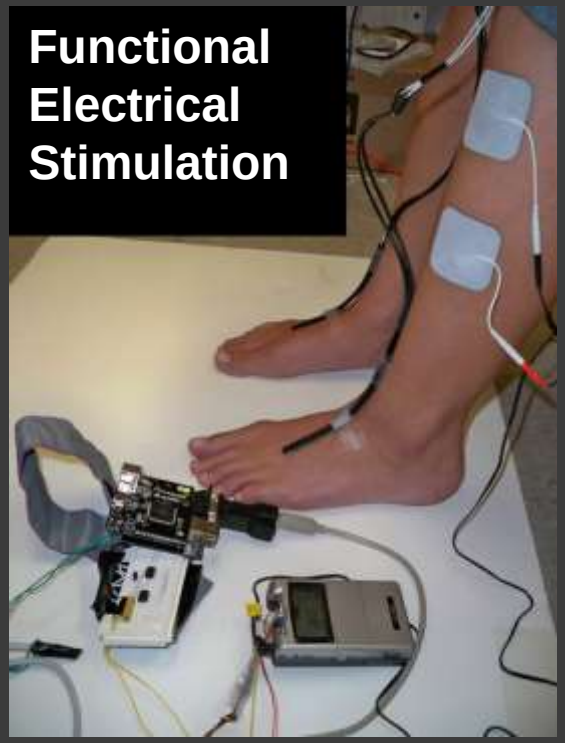
1 2 3 4 5 6 7

8 9 0 ? ! >

VR Walking Avatar

Other devices

Electric Wheelchair



Functional Electrical Stimulation

Robotic Arm

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