Intelligent systems for applications based on brain-computer interfaces: challenges and some solutions

Signal Processing and Computational Intelligent Group (PSIC)
INSTITUTO NACIONAL DE ASTROFÍSICA, ÓPTICA Y ELECTRÓNICA
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V: 2016-01-24

This presentation is available at:
http://ccc.inaoep.mx/~pgomez/conferences/PggISC16.pdf

Very glad to be here, again!

Contents

- The PSIC group in INAOE
- What is BCI?
- CI and Signal processing with BCI
- Some BCI research going on in PSIC group
- Conclusions and Perspectives

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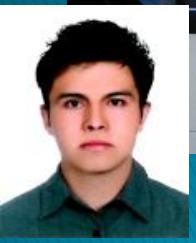
北京国际会议中心 BEIJING
Welcome to the 2014 IEEE World Congress on Computational Intelligence

About us…



INAOE

Ubicación de los Centros de Investigación Conacyt

http://www.conacyt.gob.mx/index.php/el-conacyt/centros-de-investigacion-conacyt

PSIC group (1 /2)

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- It is integrated with students and researchers from Computer Science and Electrical Engineering from INAOE, and other universities as UDLAP, Universidad Autónoma de Tlaxcala, BUAP.
- Among other subjects, we work with the development and use of algorithms for brain-computer interfaces (BCI).

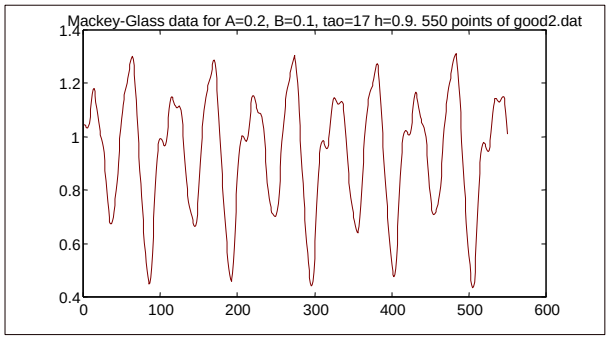
PSIC group (2/2)

- Researchers (in alphabetical order)
  - Dr. Vicente Alarcón Aquino- UDLAP
  - Dr. Israel Cruz Vega- Conacyt fellow-INAOE
  - Dr. Edgar García-Treviño – Post-doct UNAM
  - Dra. María del Pilar Gómez Gil-INAOE
  - Dr. Juan Manuel Ramírez Cortés- INAOE
  - Dra. Haydé Peregrina Barreto – INAOE
  - Dr. José Rangel Magdaleno – INAOE
- We collaborate with the "biomedical signals Lab" in computer science department and "Instrumentation group" in electrical engineering department, at INAOE

Knowledge areas

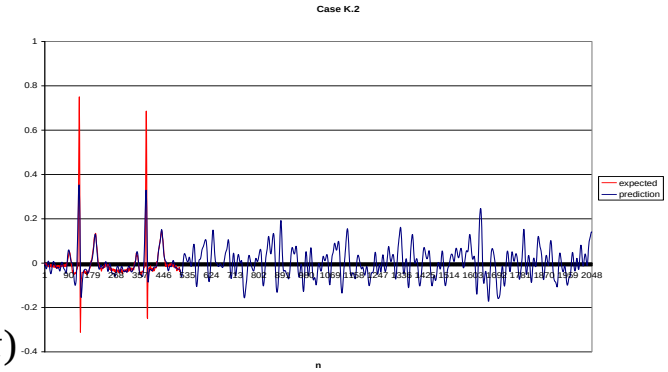
- Computational Intelligence and Machine learning – for classification and prediction.
- Signal processing – for feature extraction

Non-stationary signals

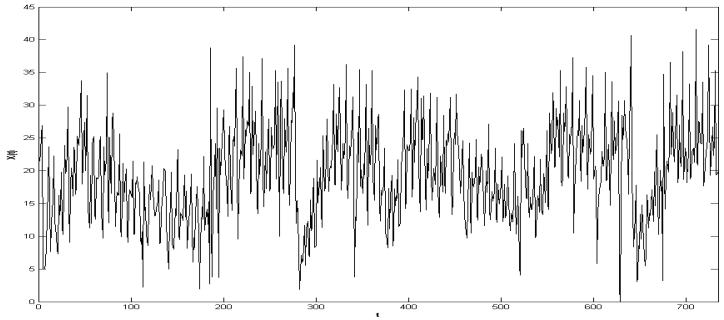


$$\frac{dx(t)}{dt} = \frac{ax(t-\tau)}{1+x^{10}(t-\tau)} - bx(t)$$

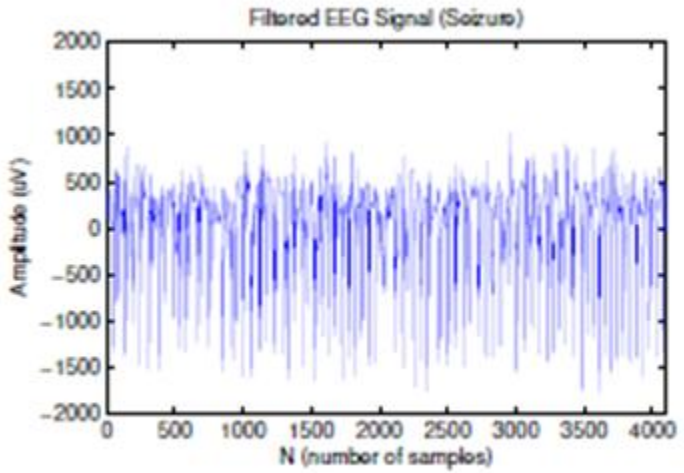
Mackey-Glass time series (Glass 1977)



Long-term prediction of an ECG (Gomez-Gil et al., 2011)



ATM withdraws (NN5-001) (Crone 2010)



EEG of an ictal state
(Juarez-Guerra, 2014)

WHAT IS A BCI?

Do you remember Star Trek TV series? Once, capitan Pike had a terrible accident, being forced to be in a wheel chair (1966)?

Pike was able to communicate with others only using brain signals

BCI was **"science fiction"** at that time!….

¿What is a BCI? (Graimann et al. 2010)

- A BCI is an artificial system, which goes over the common efferent paths of the human body,
- “Efferent” refers to a impulse that goes from the central nervous system to the muscles,
- A brain computer interface “measures” the brain activity associated to an user intention, translating it to control commands,
- Such translation requires sophisticated signal processing and patter recognition tasks.

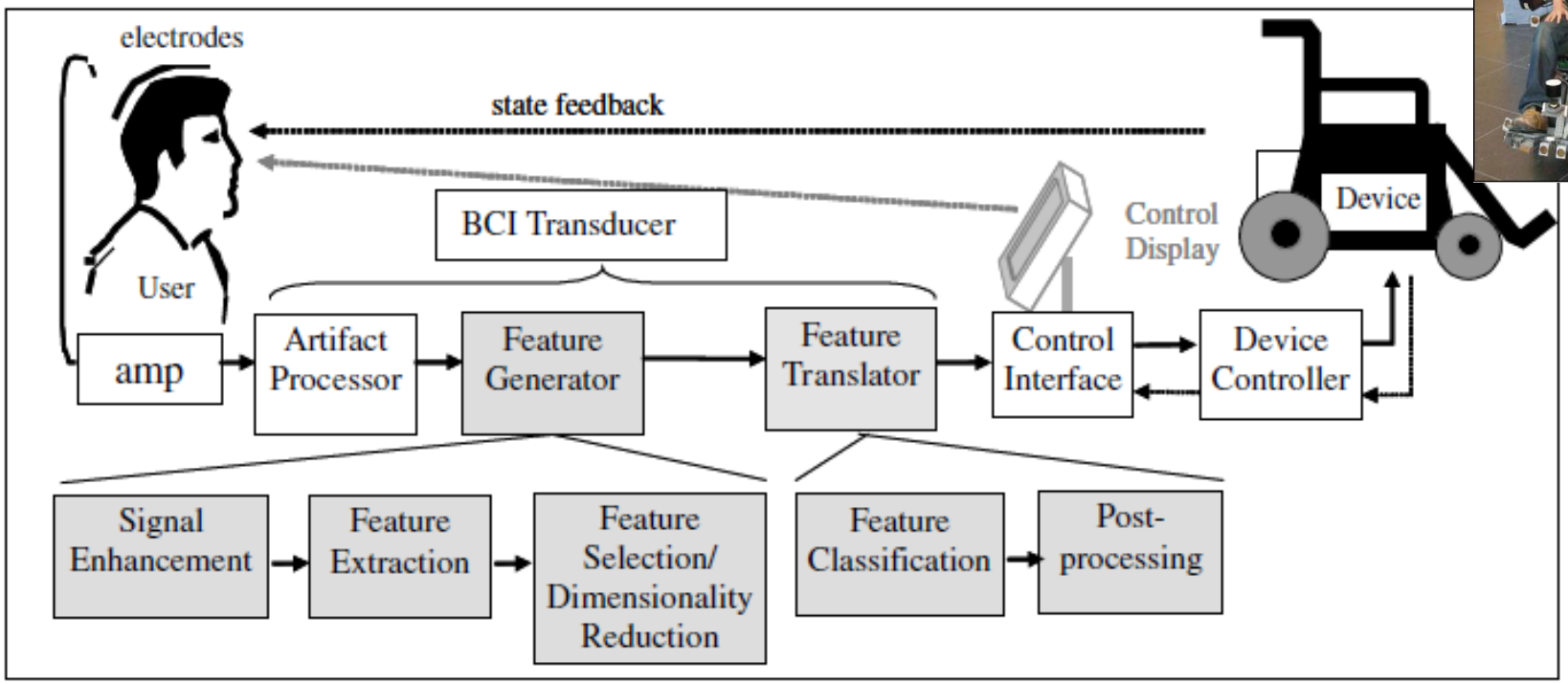
Nowdays…

Important events
(Graimann et al. 2010)

- 1929 – Hans Herber recorded the first external brain signals from the scalp (invention of the electroencephalograph)
- 1964 – Gray Walter got a patient to "turn on" a projector during a open-brain surgery – first BCI!
- 2000's – around a couple of research labs were focusing on BCI.
- 2010 – at least 100 BCI's labs
- Today – Hundreds of BCI applications helping people to get a better life, to communicate and enjoy

Gray Walter, Wikipedia

An example: BCI for wheelchair control



[D'croz Barón 2010]

Main features of a BCI

- It implies a direct gathering of brain activity, either in a non-invasive or invasive fashion.
- There is a lot of user feedback.
- It is done in real time.
- The user has an intentional control of the activities to be executed.
- BCI may be considered a “neural prosthesis”. Other kind of such prosthesis are, for example, retina implants, dorsal-cord stimulators, bladder controllers, etc.
- Also known as brain machine interfaces (BMI) or direct brain interfaces (DBI)

BCI is not a way for "reading your mind" ☺

A popular post in:

facebook

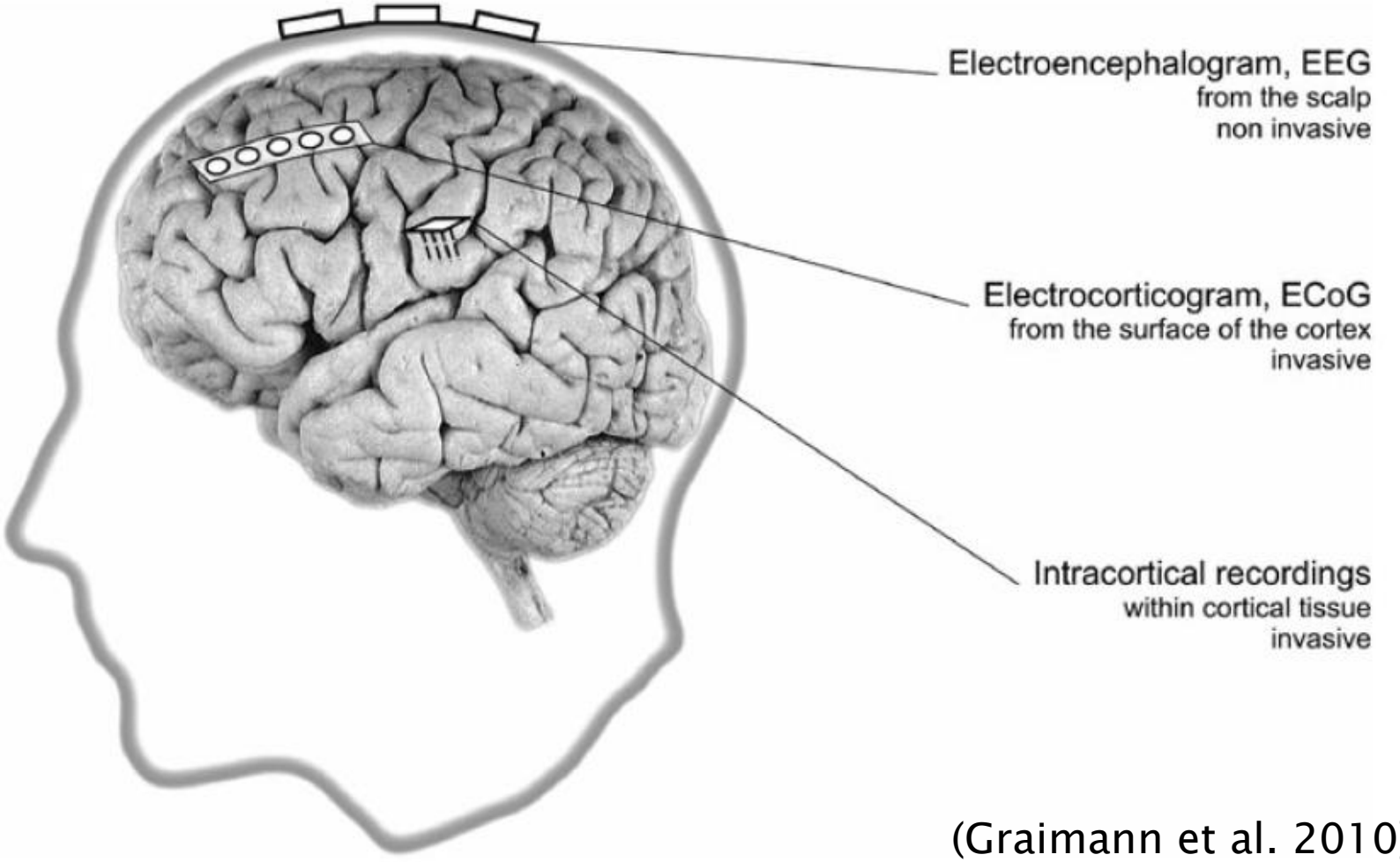
!!!WARNING!!!

Facebook is planning to start scanning your brain for private information through your computer monitor. To stop this from happening, go to Kitchen –> Cabinets –> Upper Right Drawer –> then REMOVE the box that says 'Aluminum Foil'.

Then wrap all foil around your head.

Share this to warn all your friends!

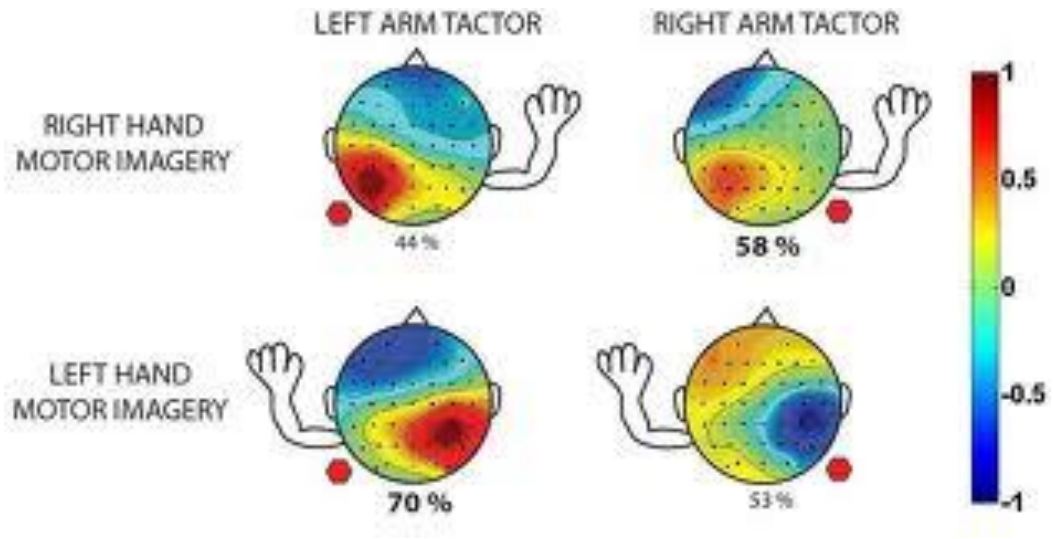
Brain activity detection



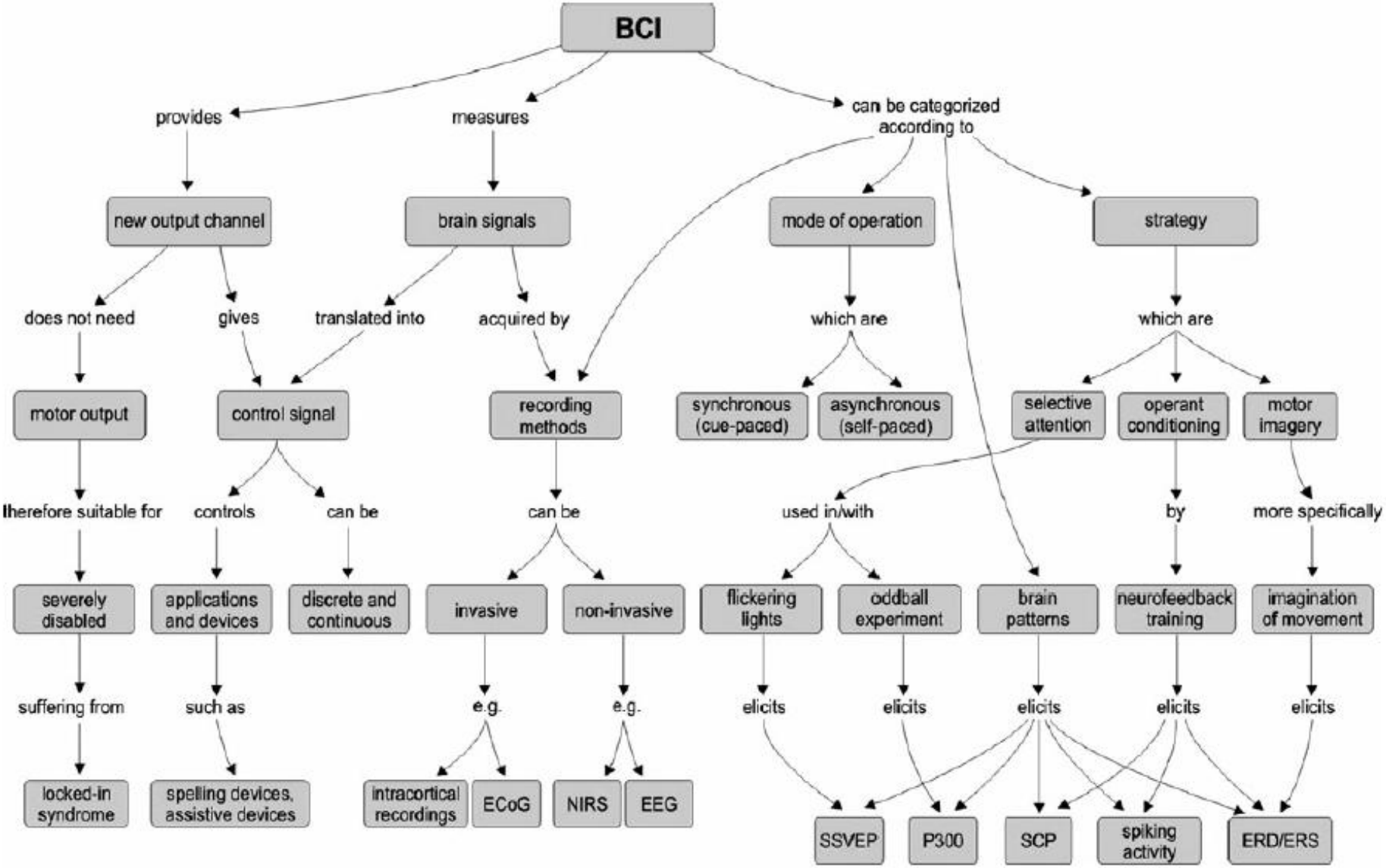
(Graimann et al. 2010)

BCI strategies

- BCI may detect and classify brain signals, which may or may not be associated to specific brain events.
- To produce such signals, the user follows what is called a “mental strategy”, being the most common:
  - Selective attention
  - Motor imaginary



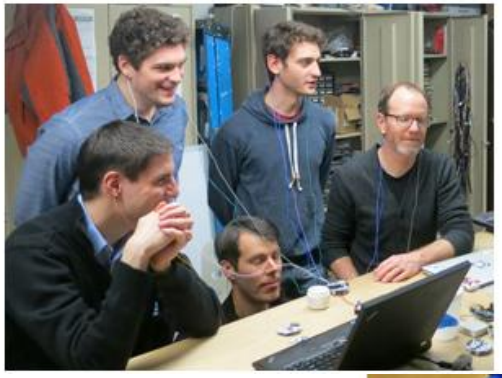
A BCI conceptual map (Graimann et al. 2010)



Some examples

- Controlling a air shark with your mind" (sep. 2015):

http://spectrum.ieee.org/geek-life/hands-on/openbci-control-an-air-shark-with-your-mind



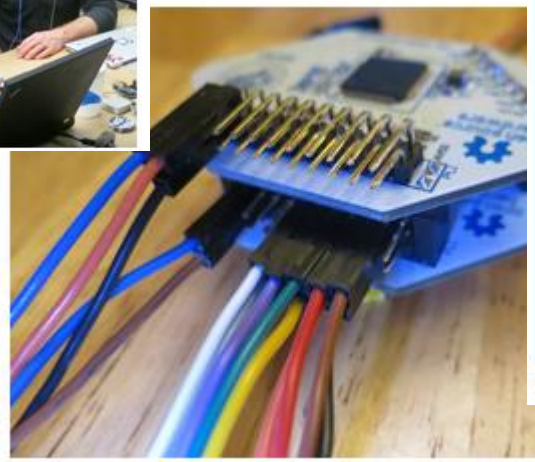
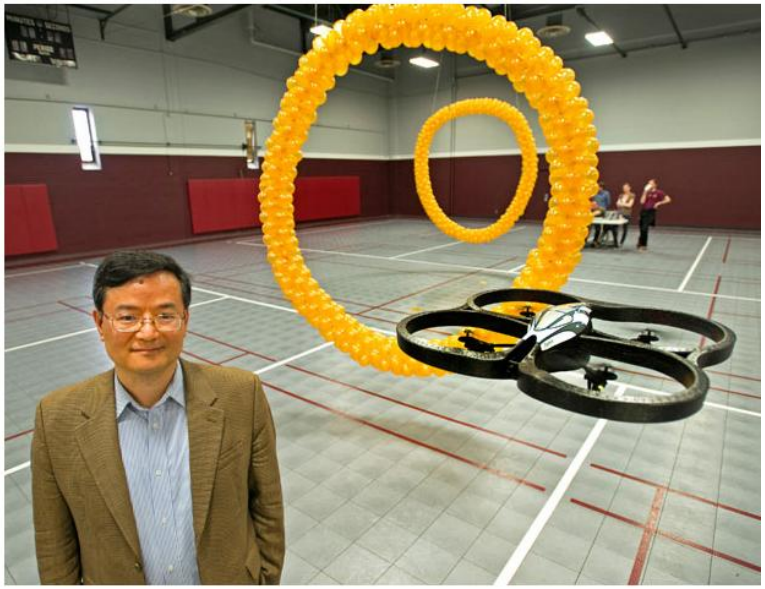
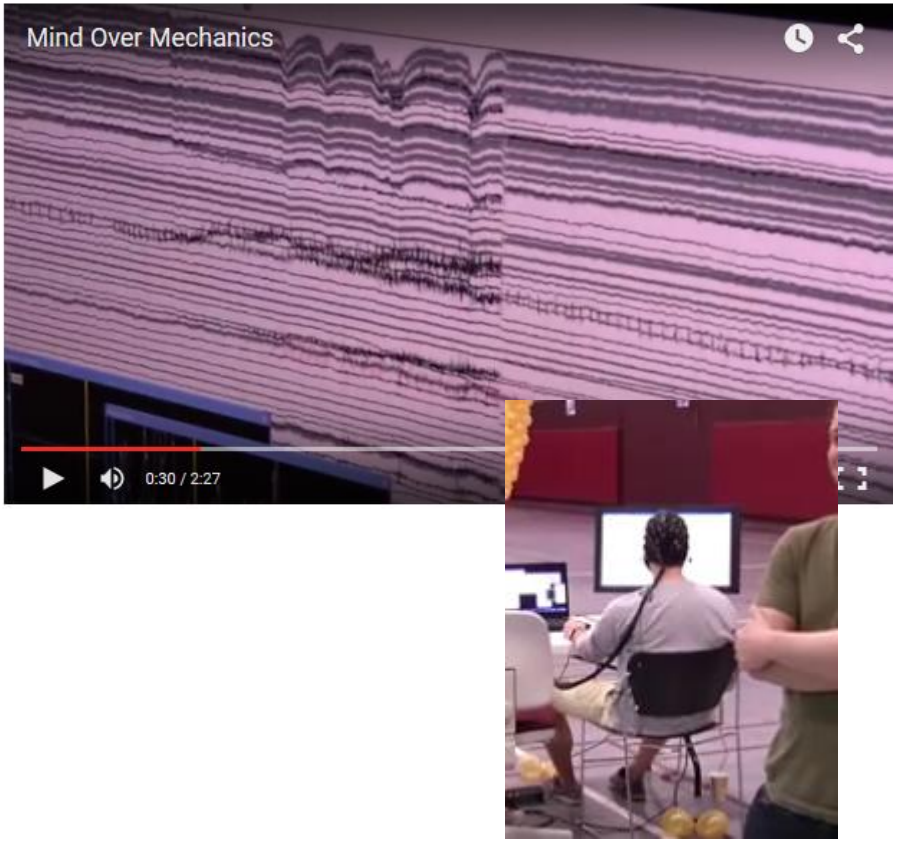


Photo: David Yellen

Flying quadrotors with your mind

- http://spectrum.ieee.org/tech-talk/biomedical/bionics/flying-quadrotors-with-your-mind

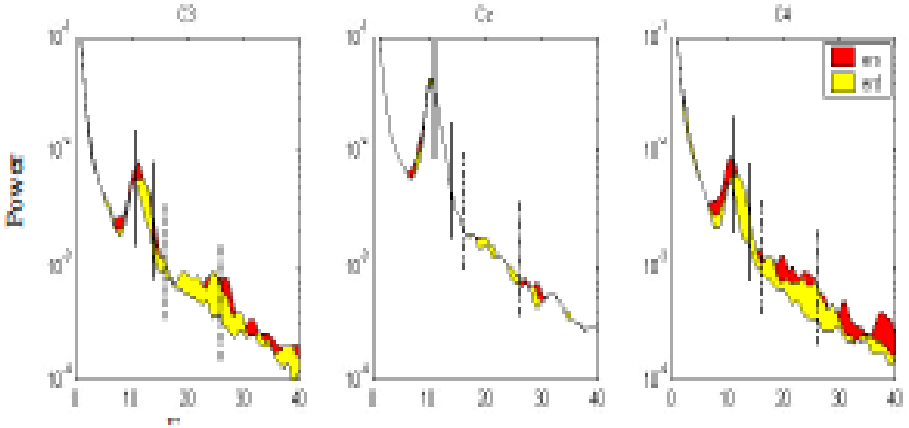


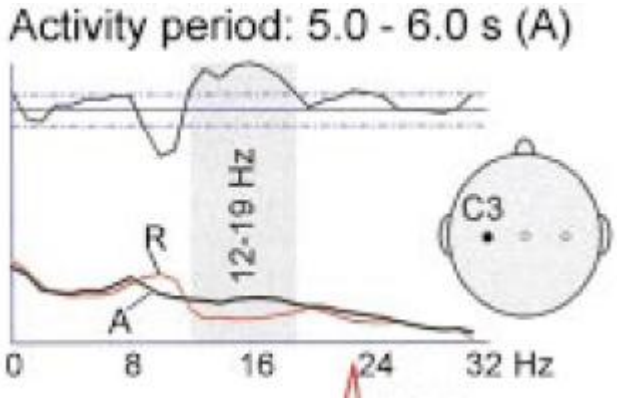


Feature extraction

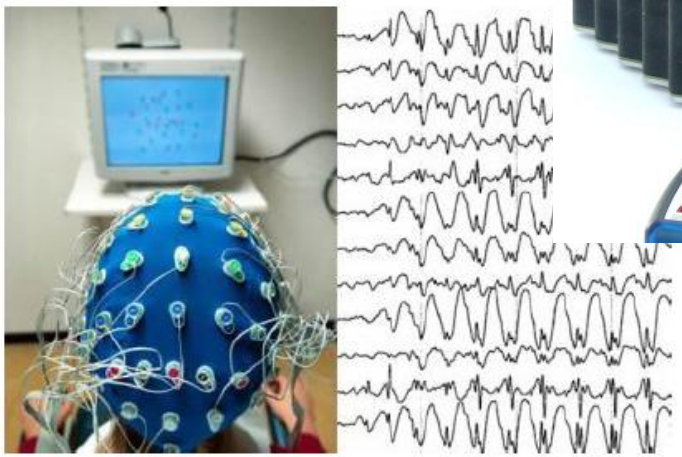
Reactive band filters

Several studies have found that, for many people, the reactive band is located around 9-13 Hz, but it may be different for different people.

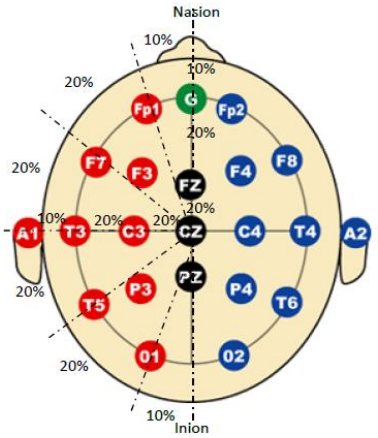




Sensing EEG signals



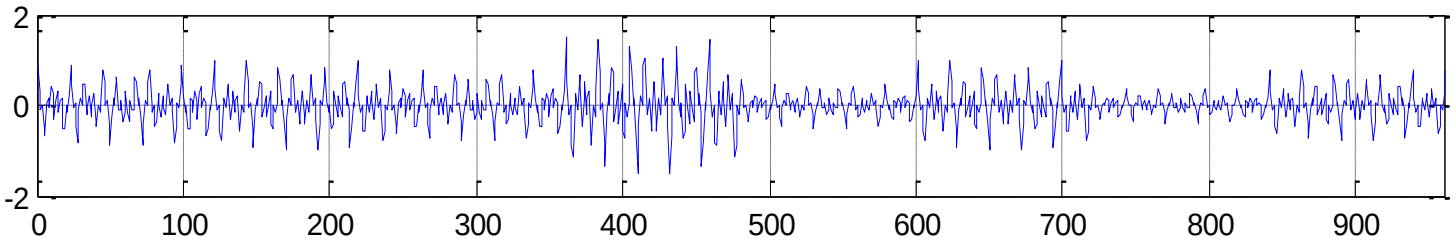
Amplifier-EEG G.Hlamp
http://www.gtec.at

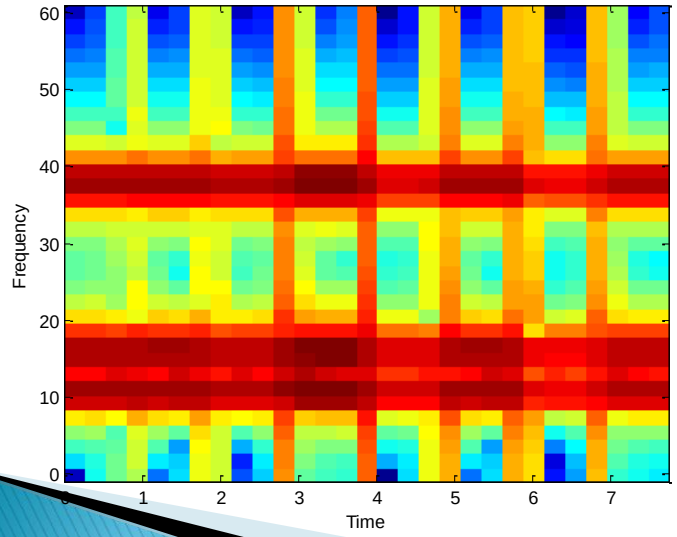


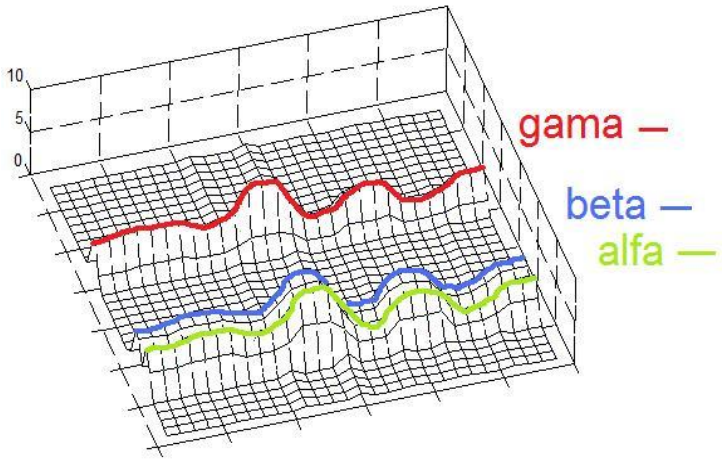
10-20 electrode placement system
(image taken from
Juárez-Guerra, 2012)

EMOTIV-EPOC
https://emotiv.com/support.php

The big challenge: getting features

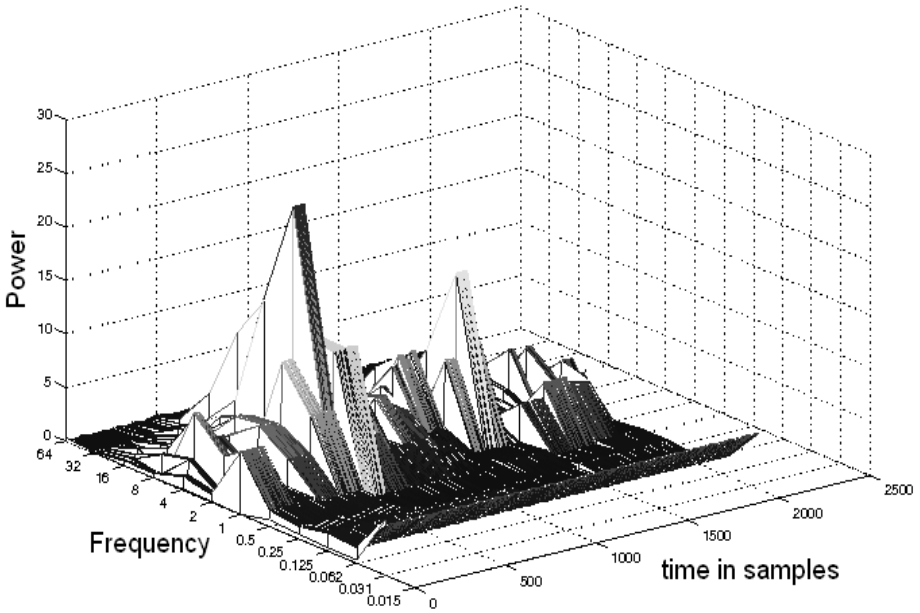


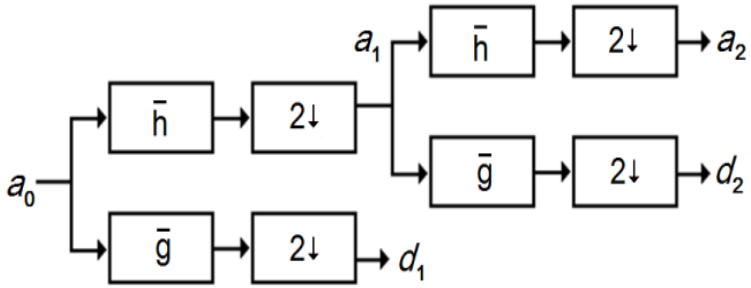




Example: Discrete wavelet transform DWT

$$W(j,k) = \sum_j \sum_k f(x) 2^{-j/2} \psi(2^{-j} x - k)$$





Wavelet : Daubechies 4

Some BCI projects in INAOE…

Controling a robot using BCI.

Commands:
1) Left
2) Right
3) Shift

BLINKY-command identifier

(Lopez-Espejel, 2015)

Blinky: a commmand identifier

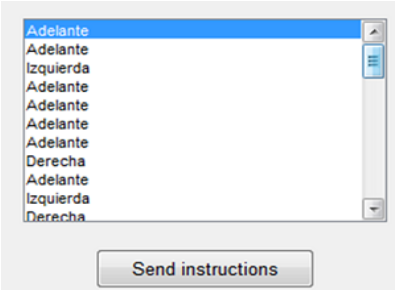
Sensing and pre-processing

Feature extraction-wavelet modeling

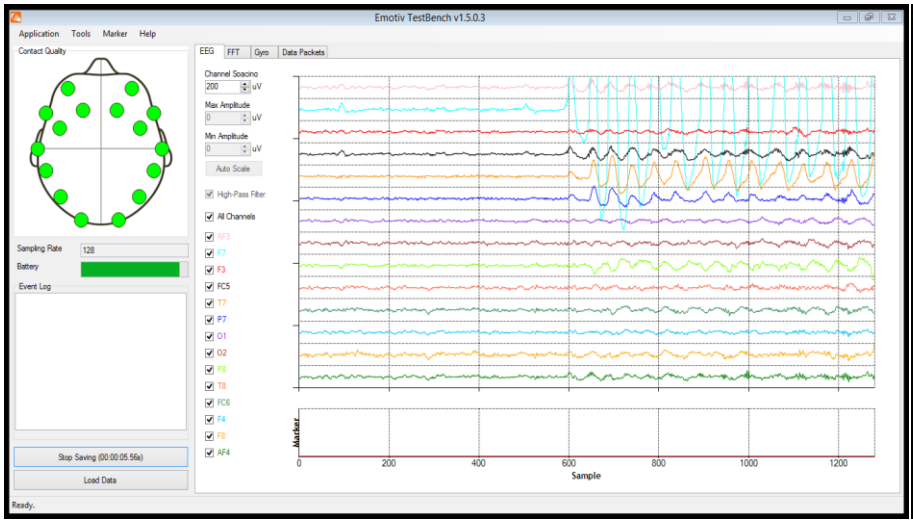
Neural net classifier

Robot coding

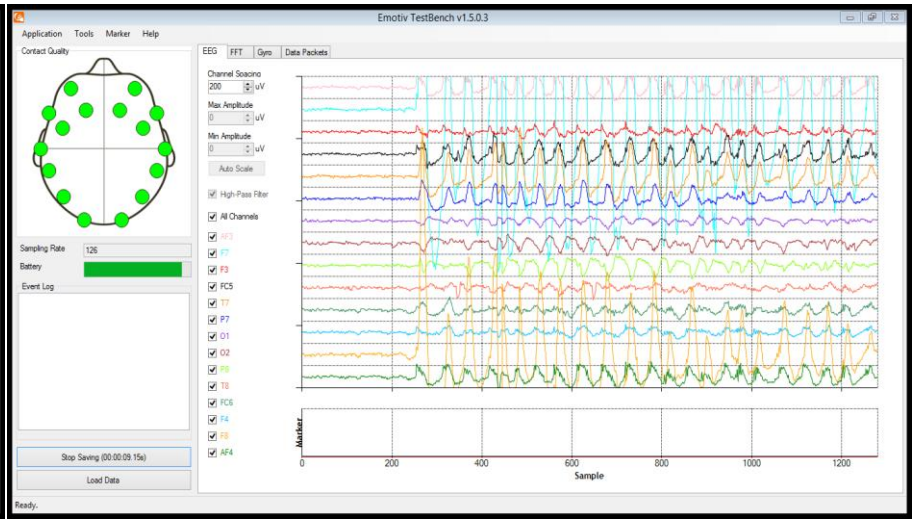
(Lopez-Espejel, 2015)



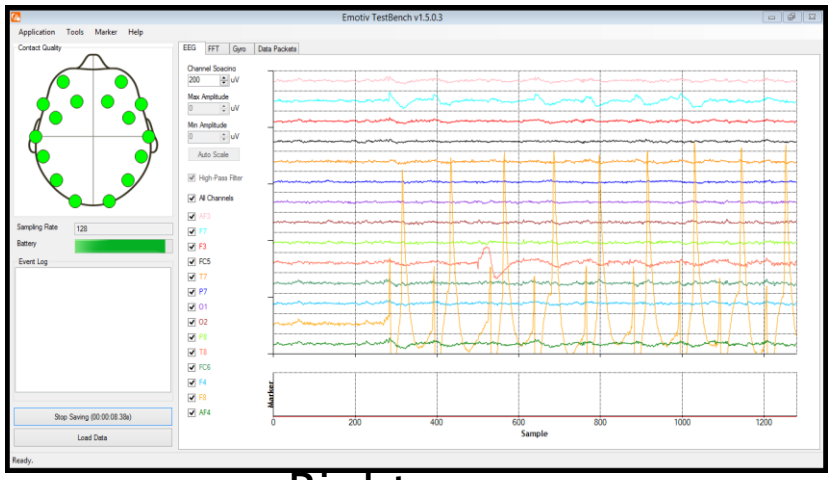
EEG during blinking eyes



Left eye

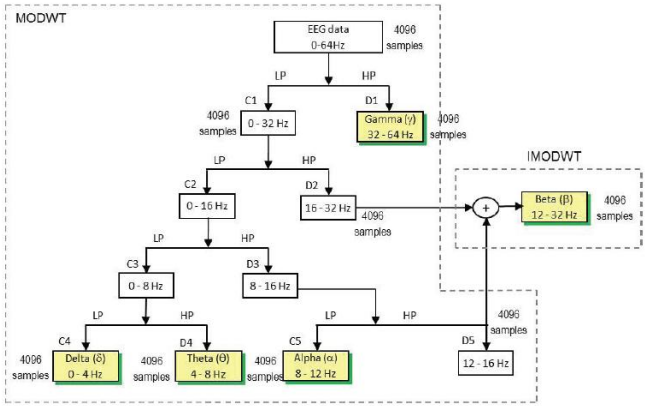


Both eyes.

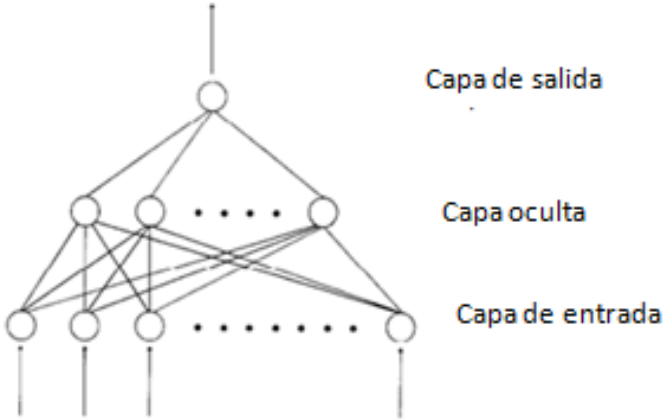


Right eye

Current models and results of Blink



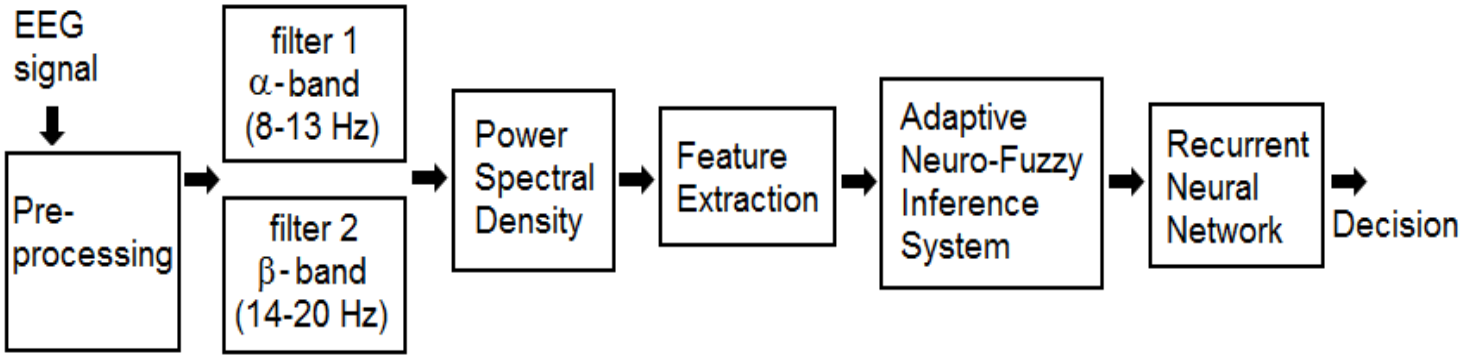
(Juarez-Guerra, 2014)

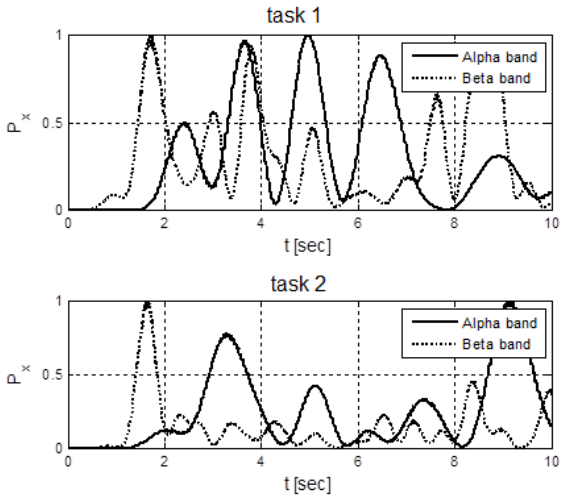


- Feature extraction using statistics over wavelet coefficients
- Classification using feed-forward neural networks
- 3 subjects were involved
- Best case: 84% of recognition, using 5 input neurons and 20 output neurons.

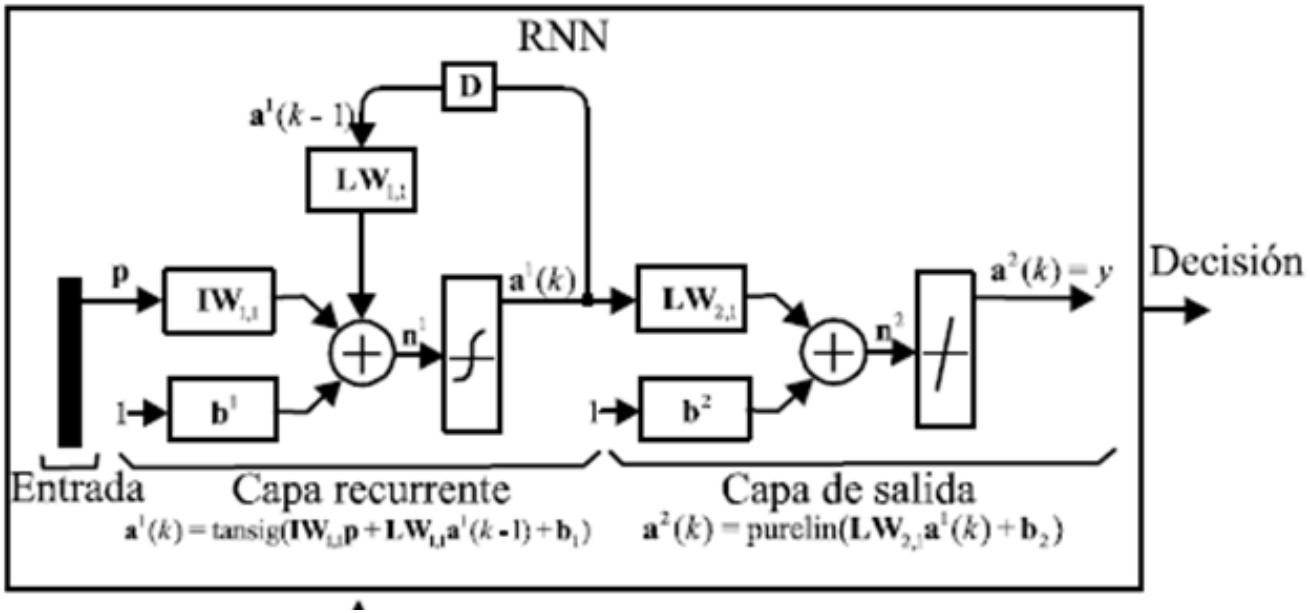
ERD/ERS detection during mental tasks, using recurrent neural networks

(Morales-Flores et al. 2013)



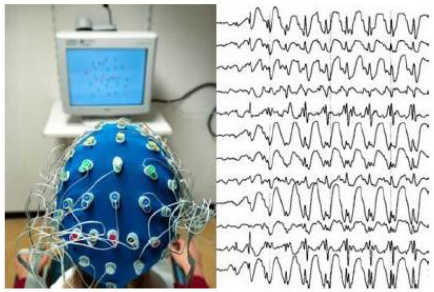


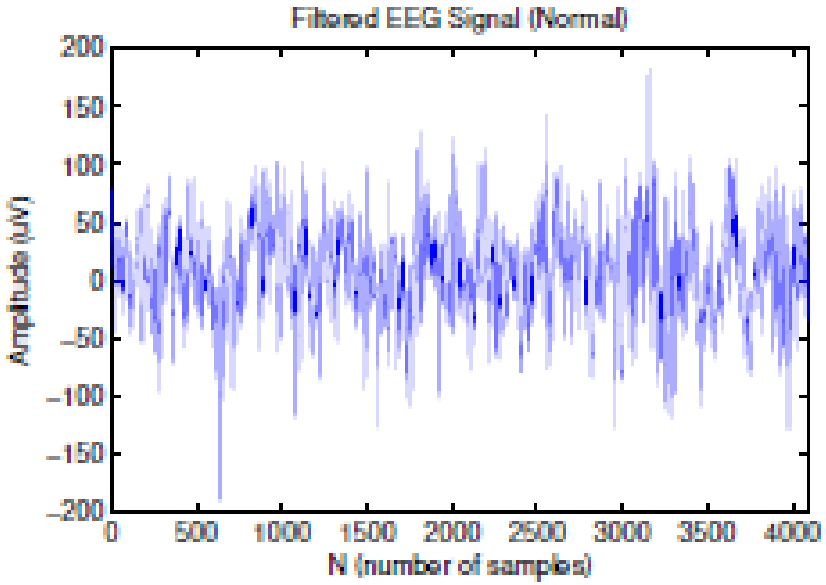
Recurrent Neural Network



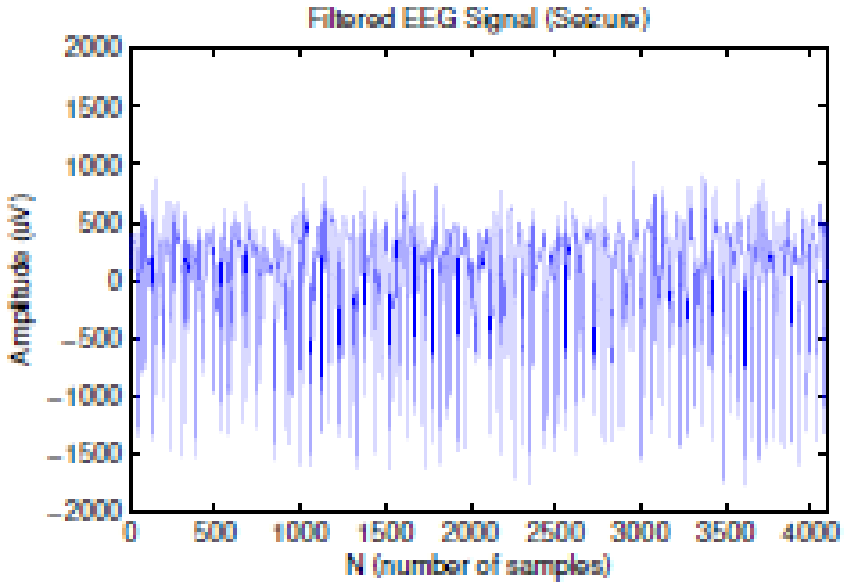
(Morales-Flores et al., 2013)

Classification of ictal, inter-ictal and no-ictal events



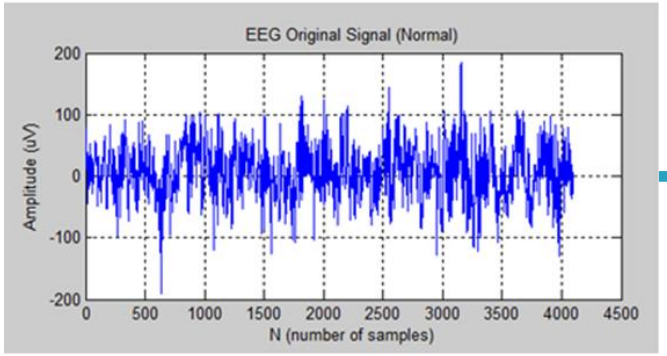


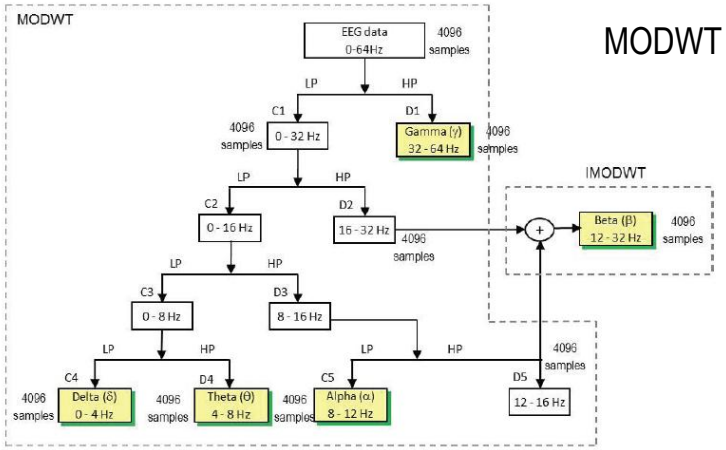
Paciente sin eventos



Durante un evento ictal

Biomedical Signal Processing Using Wavelet Based –Neural Networks

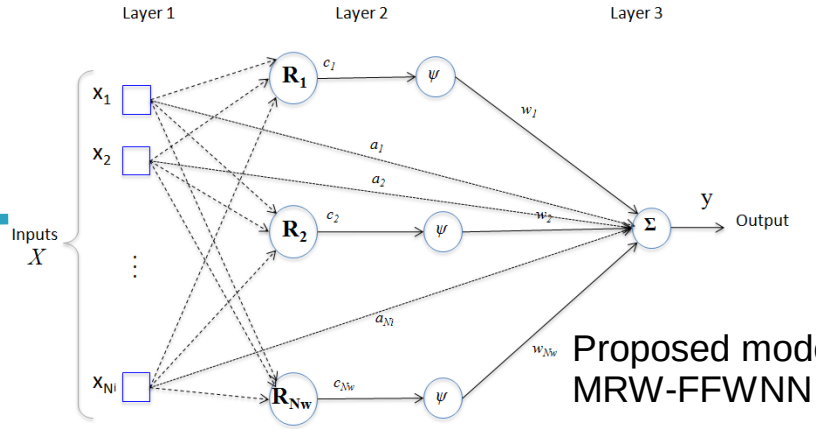




MODWT

(Juarez-Guerra, 2014)

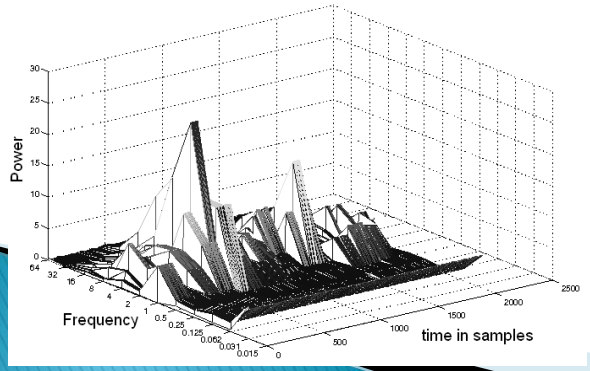
	MRW_SRWNN (% Accuracy)				
otal	Ictal	Inter	Healthy	Indeter	Total
3.11	64.44	77.06	98.42	16.44	83.56
5.56	77.24	87.62	92.00	13.78	**86.22**



Proposed model: MRW-FFWNN

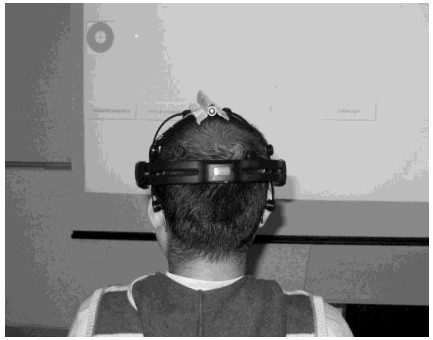
EEG signal analysis

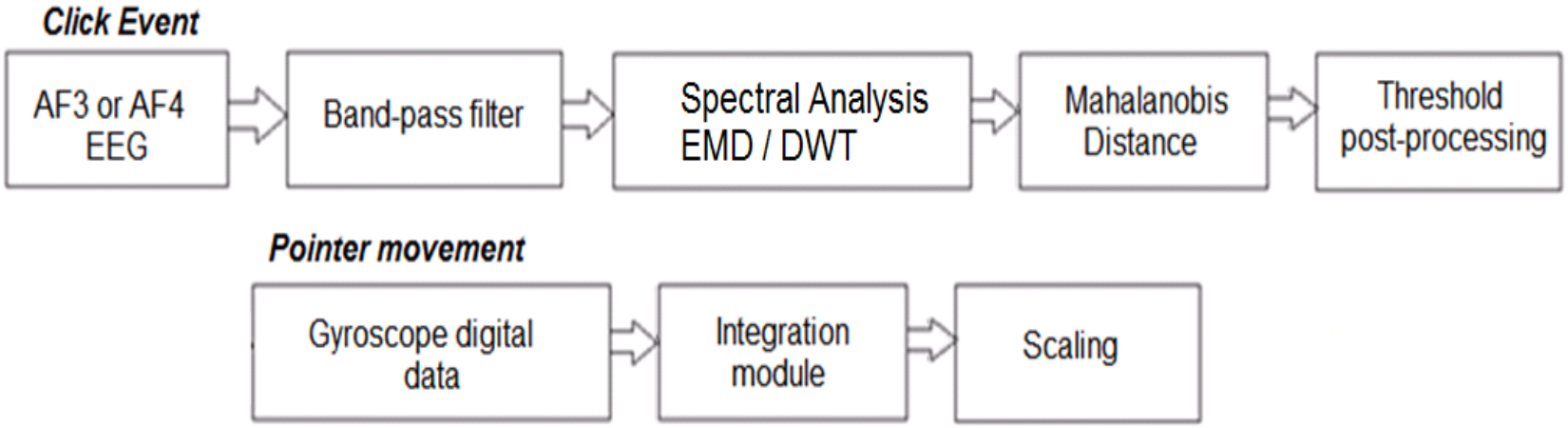
- Detecting P300 waves using DWT and independent component analysis (Gerardo Rosas; INAOE, 2011)



Detecting and using wavelet analysis and common spacial patterns (Obed Carrera y David D´Croz; INAOE-Texas Tech; 2011)

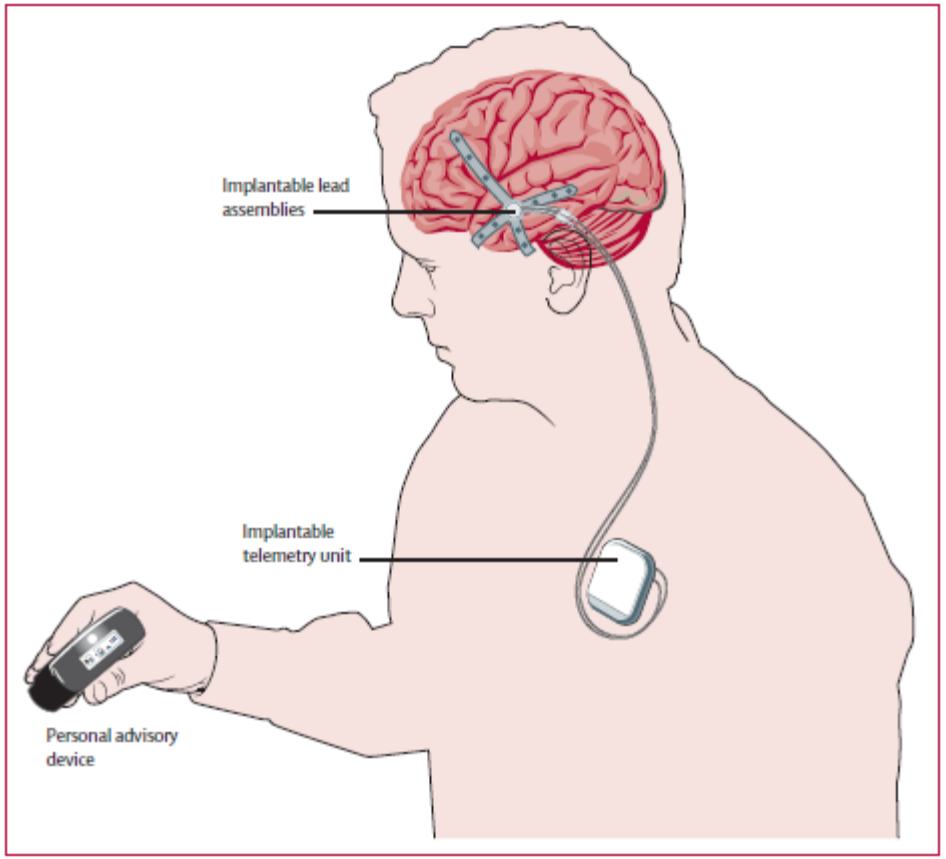
Blinking detection and gyroscope processing system





(Rosas-Cholula et al., 2013)

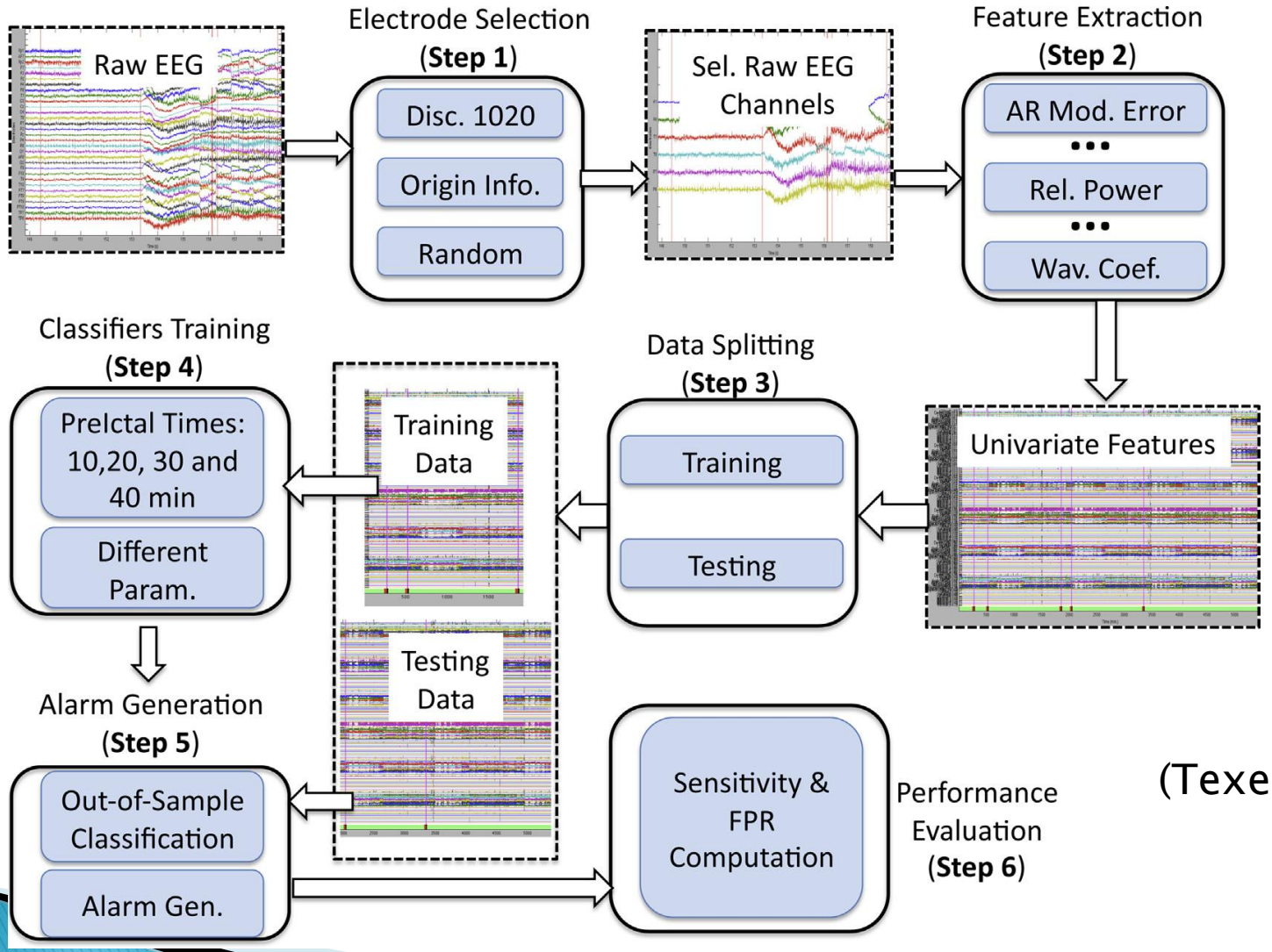
Our new project: prediction of epylepsy



(Cook et al. 2013)

Figure 1: **Major components of seizure advisory system**
Intracranial electrode arrays (location shown by grey areas) were used to collect intracranial electroencephalogram (EEG) data on the cortical surface. Leads were connected to a subclavicularly placed implanted telemetry unit, which wirelessly transmitted data to an external, hand-held personal advisory device. The external device received the telemetered EEG, applied an algorithm to the data, and displayed the resultant information as a series of advisory lights—blue (low), white (moderate), or red (high) indicators—in addition to an audible tone or vibration, or both. The hand-held device could be worn on the belt or carried in a bag.

A model for predicting seizures



(Texeira, 2014)

Conclusions and perspectives

- BCI are here to stay!
- The practical use of BCI is a real fact today, however it requires of highly trained users, reliable sensors and excellent processing and classification techniques
- Therefore, a lot of research is needed!
- Multi-disciplinary teams are “a must” in this kind of research

Some publications

- 2015. López-Espejel, Jessica N. "Control de movimiento de objetos a través del uso de electro-encefalogramas y redes neuronales artificiales con equipo de bajo costo. " Tesis para obtener el título de Licenciada en Ingeniería en Ciencias de la Computación. Benemérita Universidad Autónoma de Puebla- Instituto Nacional de Astrofísica, Óptica y Electrónica, Puebla. México. *To be published*
- 2013. Morales-Flores E Ramírez-Cortés JM, Gómez-Gil P, Alarcón-Aquino V. "Brain Computer Interface Development Based on Recurrent Neural Networks and ANFIS Systems". Soft Computing Applications in Optimization, Control, and Recognition, Vol. 294, pp. 215-236, Edited by Melin, P and Castillo, O, doi=10.1007/978-3-642-35323-9_9. Springer Berlin Heidelberg.
- 2013. Rosas-Cholula G, Ramirez-Cortes JM, Alarcon-Aquino V, Gomez-Gil P, Rangel-Magdaleno J, Reyes-Garcia C. "Gyroscope-Driven Mouse Pointer with an EMOTIV® EEG Headset and Data Analysis Based on Empirical Mode Decomposition." Sensors 2013, 13, 10561-10583; doi:10.3390/s130810561. *(cited at JCR Science-Edition 2012*)

Some publications(cont)

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