Introduction to Brain-Computer Interfacing

District 3, Concordia University
May 2015
18:00 ~ 21:00

BCI Montreal

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Brain-Computer Interfaces (BCI)
http://www.meetup.com/bci-Meetup

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Who are you?

Prerequisites for this workshop

Knowledge
- Basic concepts in Python (general programming experience)
- Basic signal processing concepts (such as array representation in NumPy or MATLAB)

Software
- Windows operating system
- MuLES (MuSAE Lab EEG Server)
- Python + NumPy
- Muse SDK

Hardware
- Bluetooth receiver on computer
- Muse EEG headband (supplied by us)

Others
- A brain

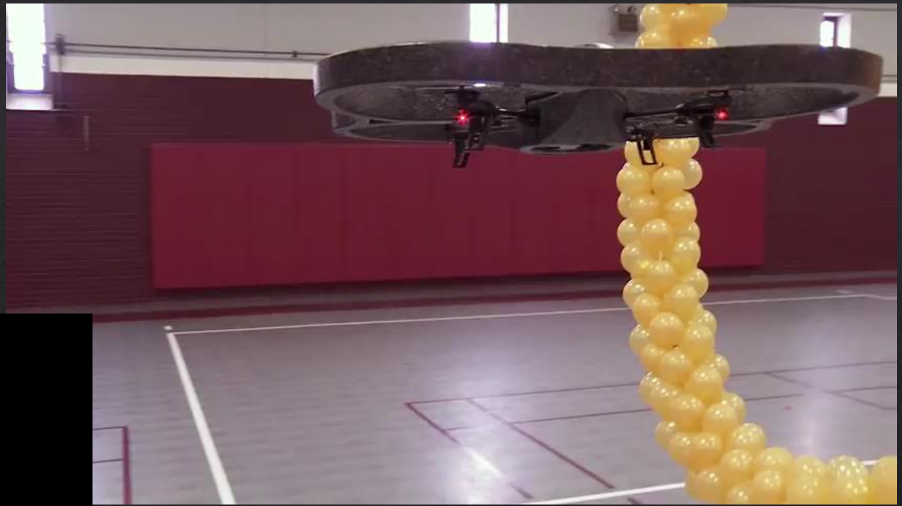
Outline

1. Background material: Why use the brain as an input, and how?
2. **Exercise 1**: a simple neurofeedback interface
3. **Exercise 2**: a basic BCI
4. Next steps and conclusion

“A **brain-computer interface** is a system that measures central nervous system (CNS) activity and converts it into artificial output that replaces, restores, enhances, supplements, or improves natural CNS output and thereby changes the ongoing interactions between the CNS and its external or internal environment.” Wolpaw 2014

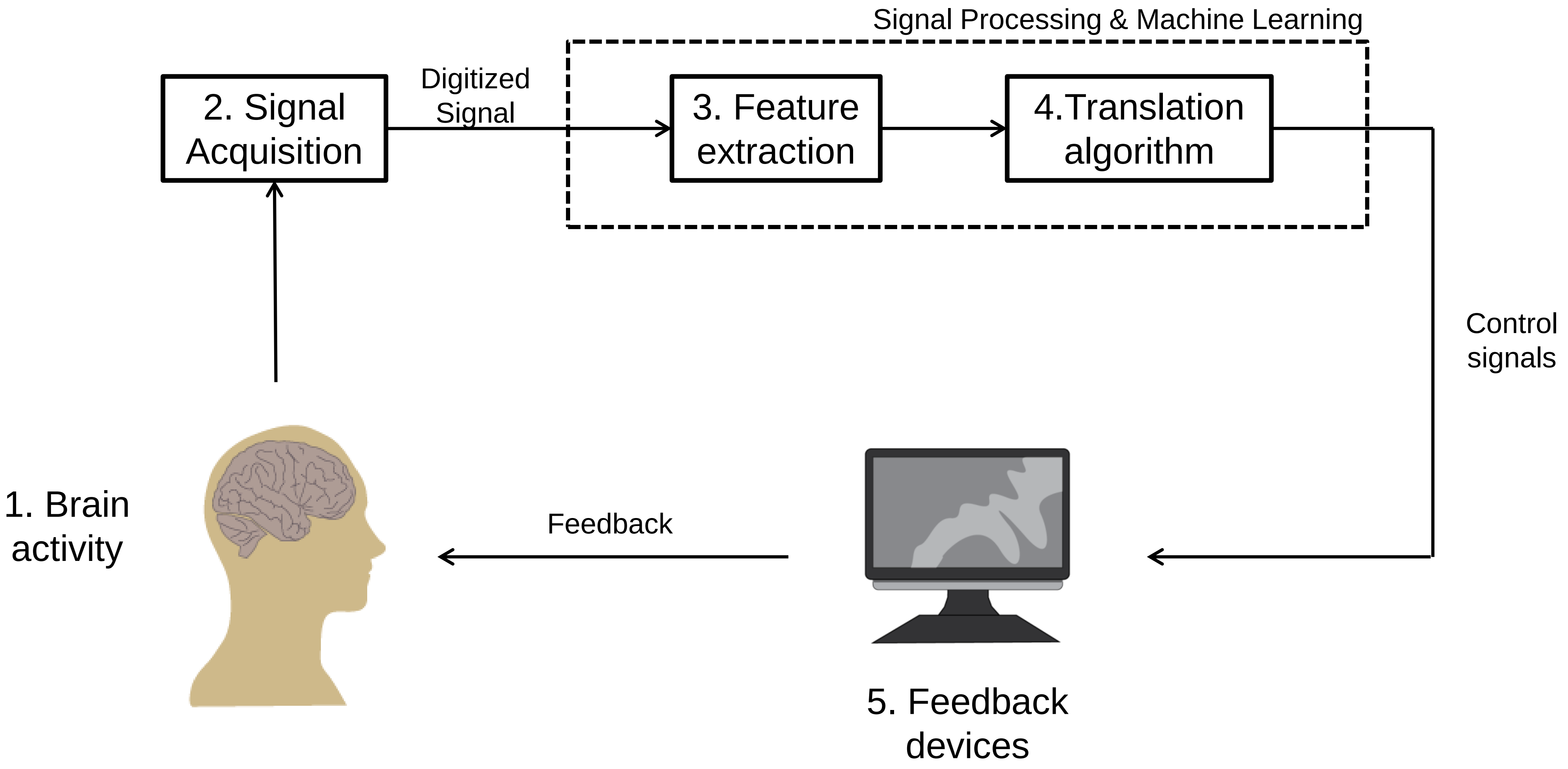
Wodlinger, B., et al. (2015). Ten-dimensional anthropomorphic arm control in a human brain–machine interface: difficulties, solutions, and limitations. *Journal of neural engineering*, *12*(1), 016011.

LaFleur, K., et al. (2013). Quadcopter control in three-dimensional space using a noninvasive motor imagery-based brain–computer interface. *Journal of neural engineering*, *10*(4), 046003.



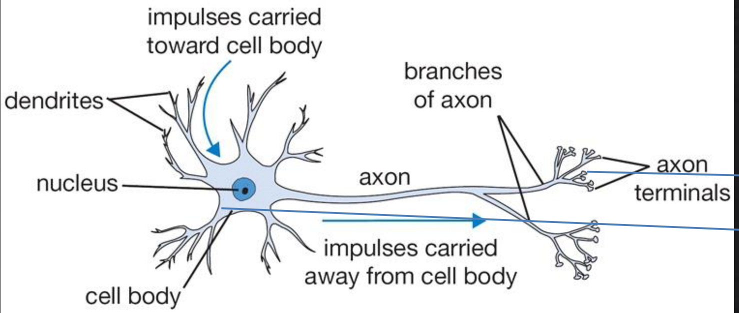
Park, L. (2013) Eunoia, http://thelisapark.com/#/eunoia.

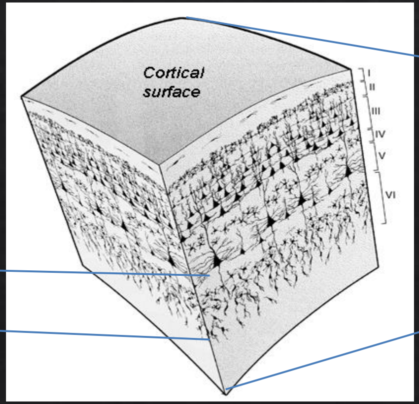
A typical brain-computer interface

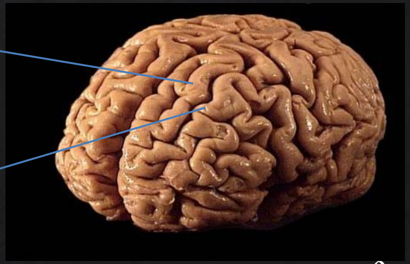


1. Brain activity

- Large-scale neuron dynamics give rise to electromagnetic activity (e.g. 50k neurons firing at once)
- 2 main types of activity for BCIs:
  - Event-Related Potentials (ERPs)
  - Oscillatory processes







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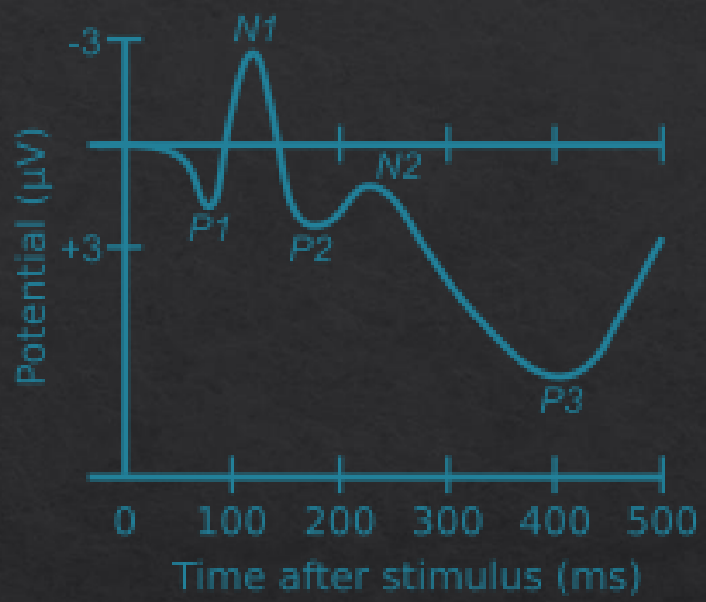
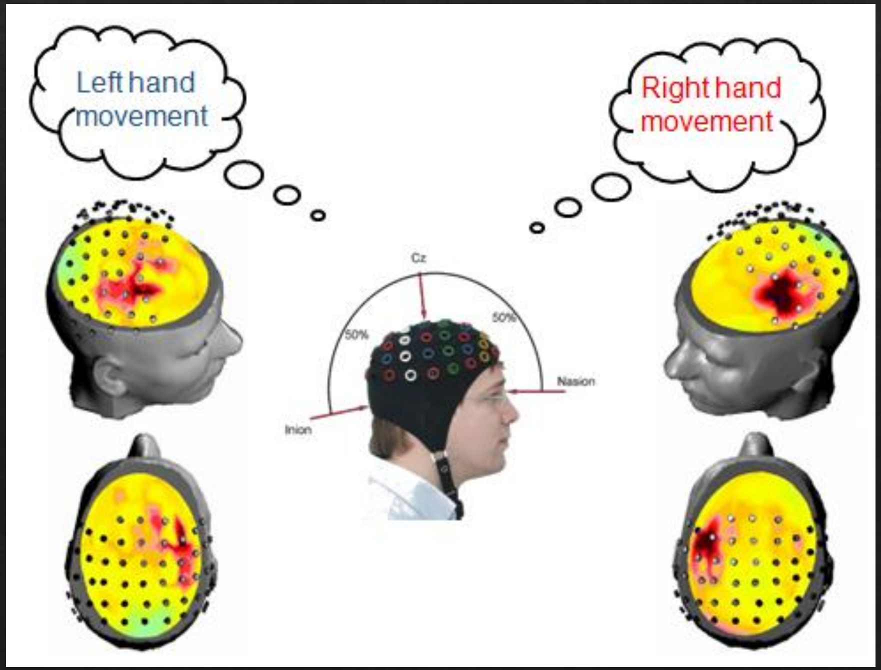


Event-Related Potentials (ERPs)

- P300: positive deflection in EEG 300ms after a rare stimulus occured

Oscillatory processes

- Motor imagery: desynchronization of the EEG when (thinking about) moving
- Alpha activity

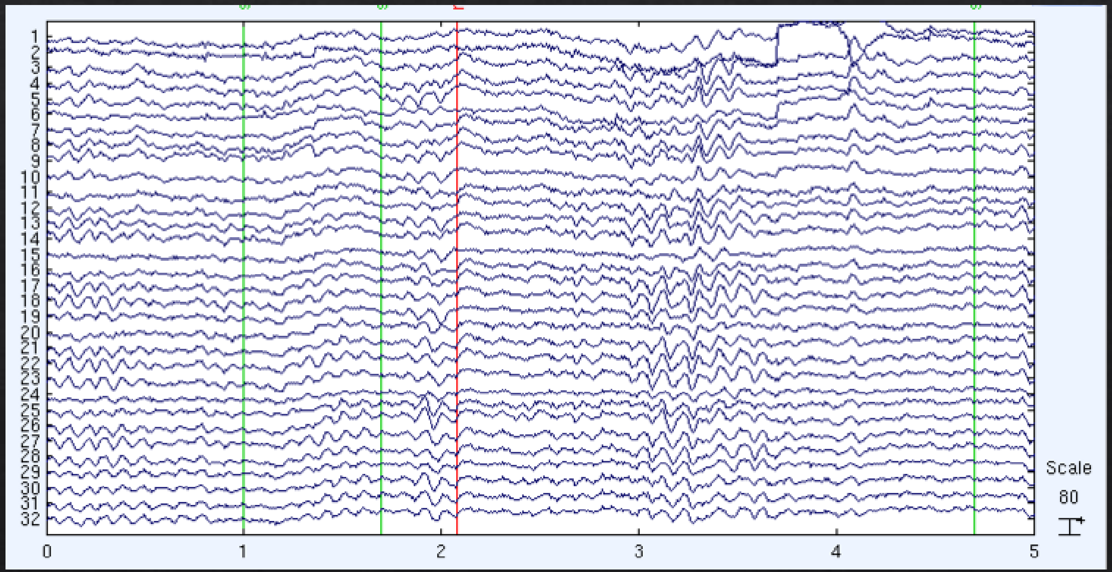


Non electromagnetic activity (NIRS, fMRI…)

2. Signal acquisition

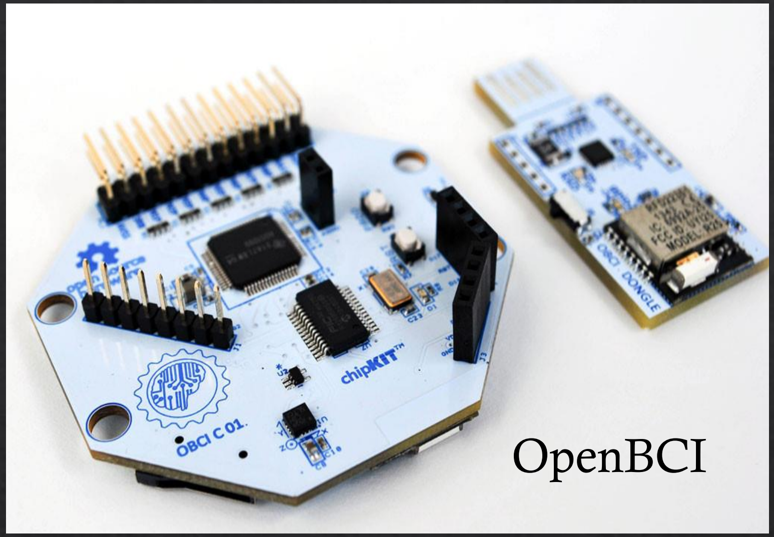
We can measure the electrical activity of the brain using sensors.

- Electroencephalography (EEG)



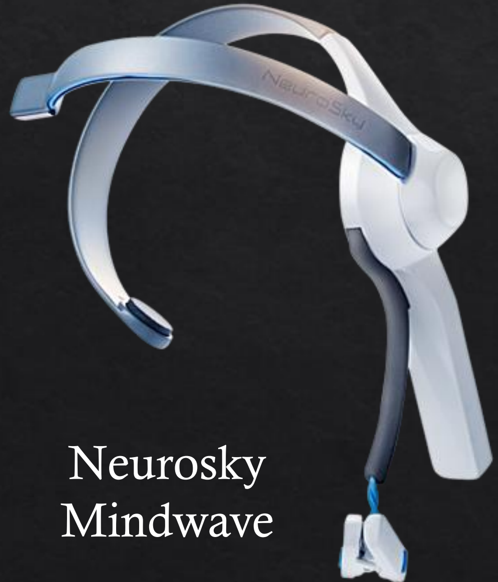
Consumer EEG headsets

Interaxon Muse



OpenBCI

Neuroelectrics Enobio



Neurosky Mindwave

Emotiv EPOC

Emotiv Insight

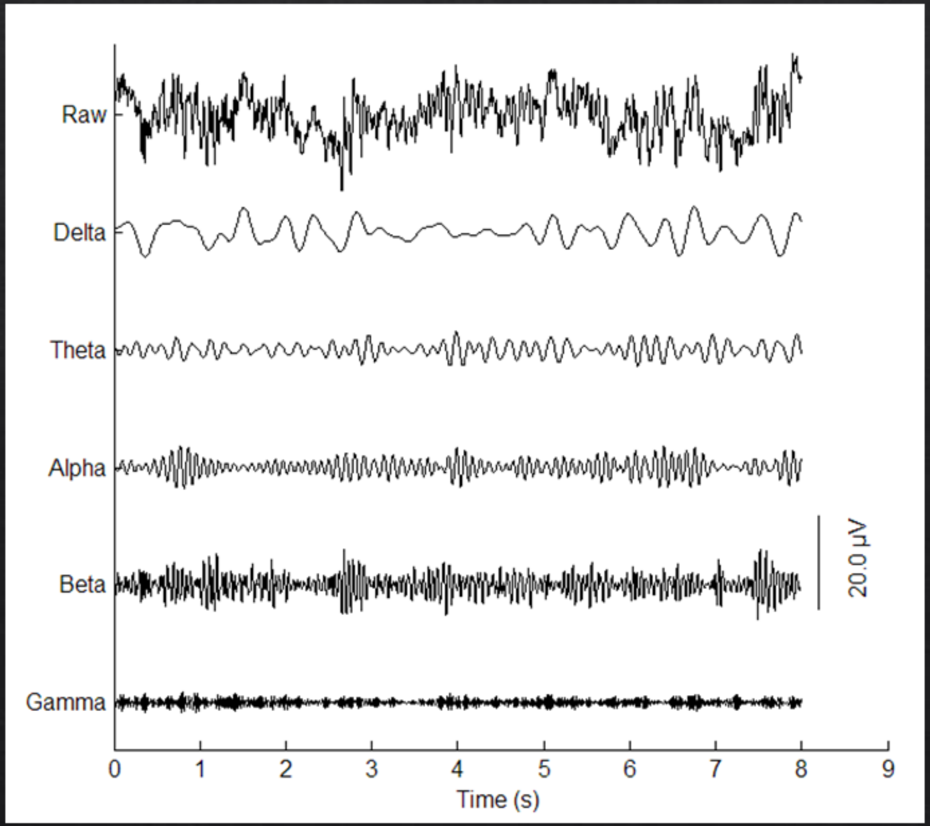
Melon

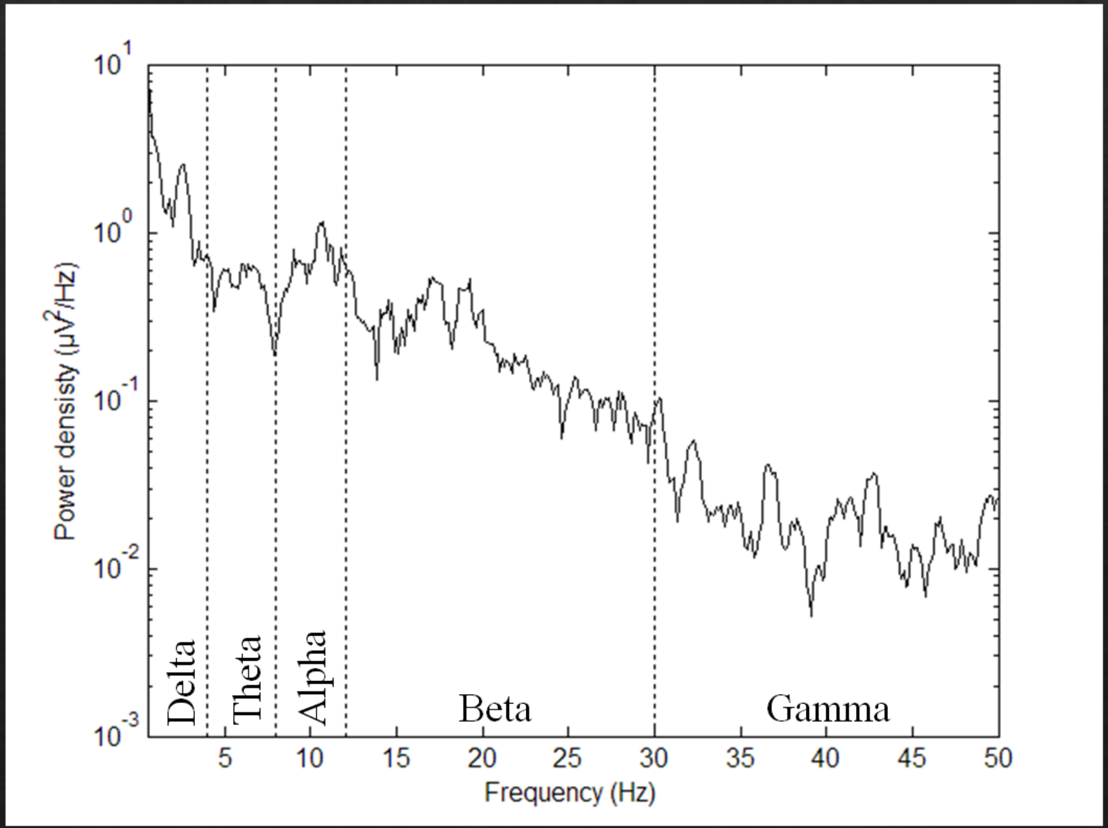
3. Feature extraction

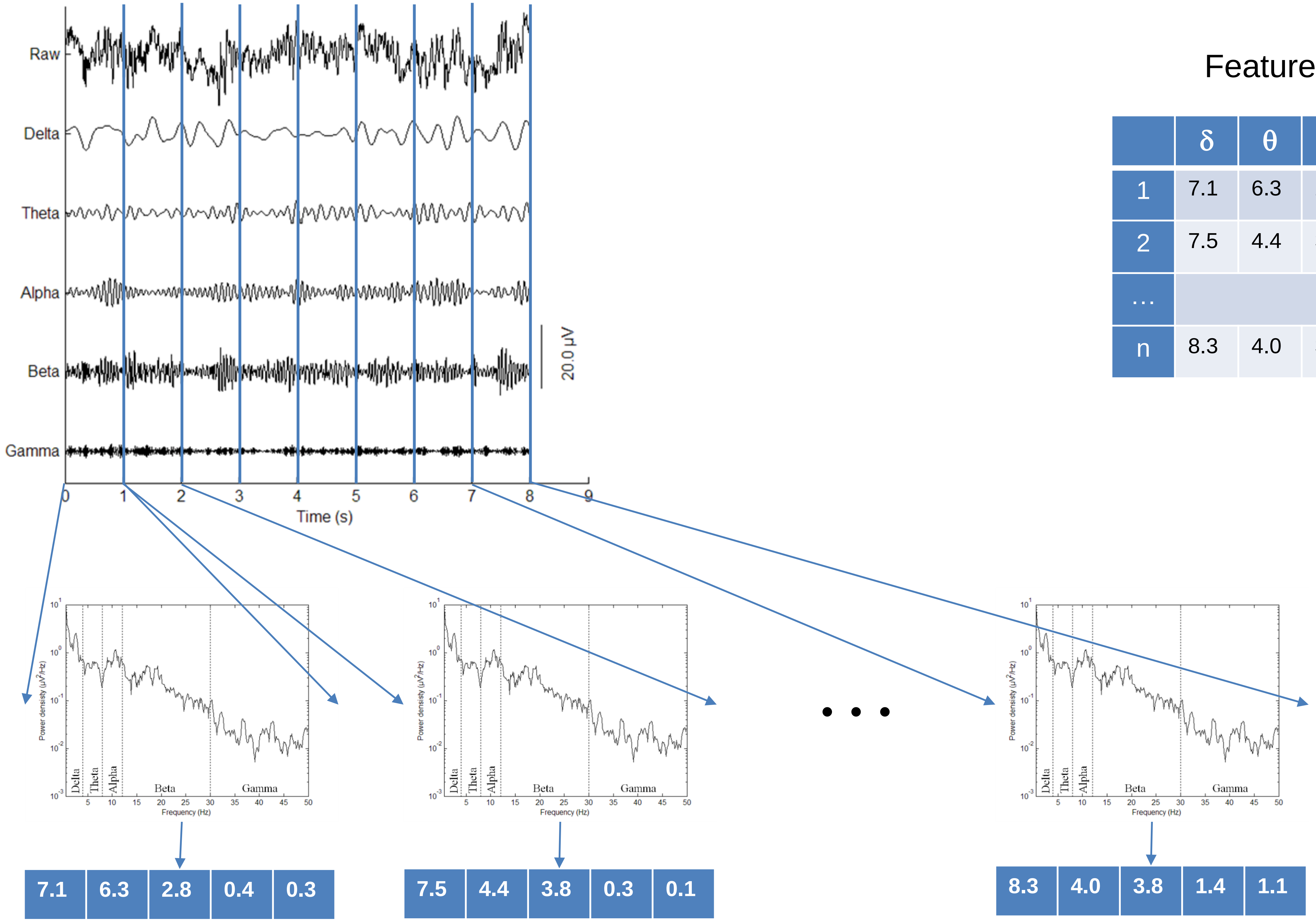
EEG is great, but too complex and noisy when “raw”.

We need to compute **features** that are more insightful (statistics of the EEG signal, **frequencies**, etc.)

Raymundo Cassani, 2015





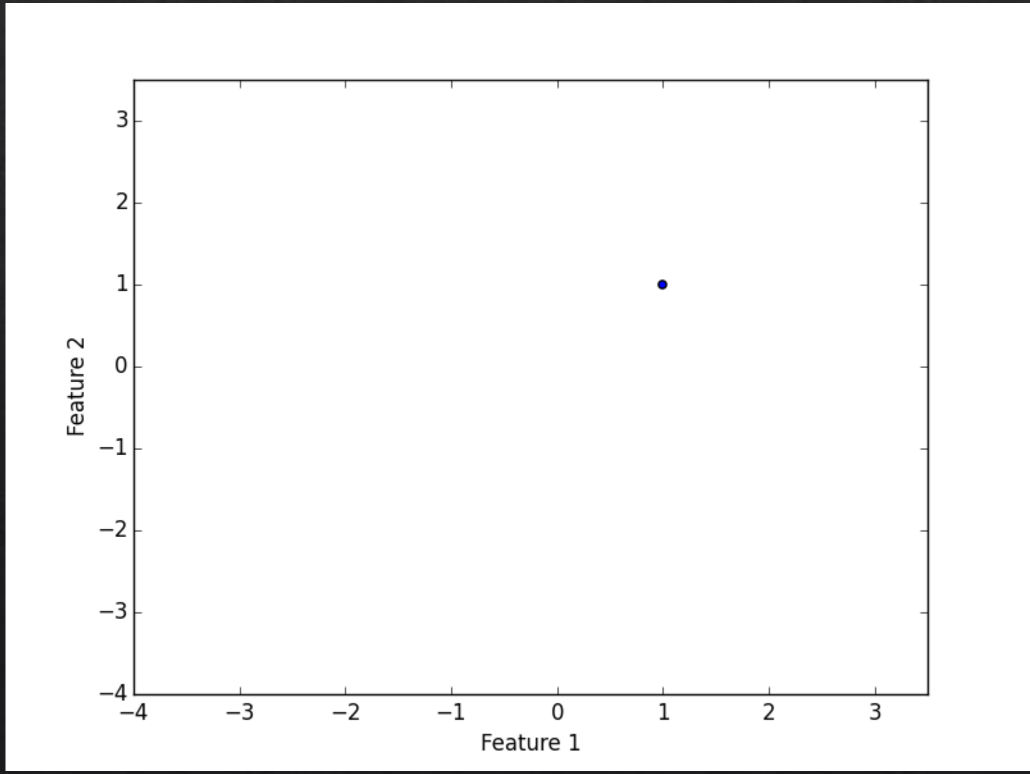


Feature matrix

	δ	θ	α	β	γ
1	7.1	6.3	2.8	0.4	0.3
2	7.5	4.4	3.8	0.3	0.1
…	…				
n	8.3	4.0	3.8	1.4	1.1

4. Translation algorithm

We use a classifier (machine learning) to find the optimal way of separating two mental activities from their features



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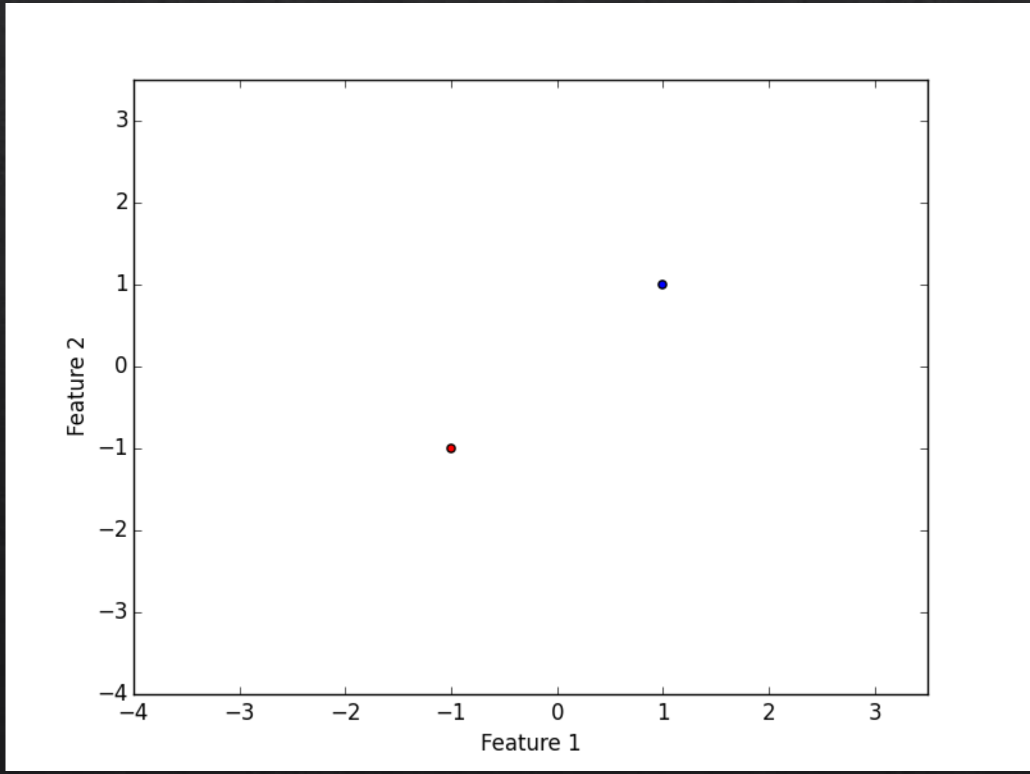

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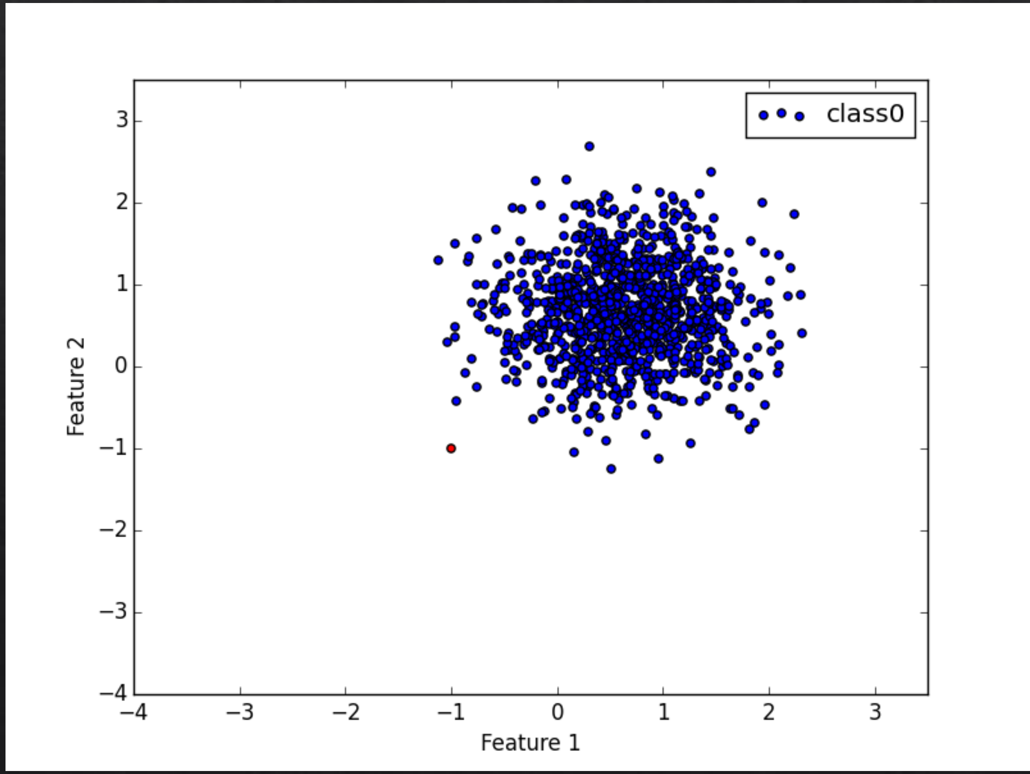

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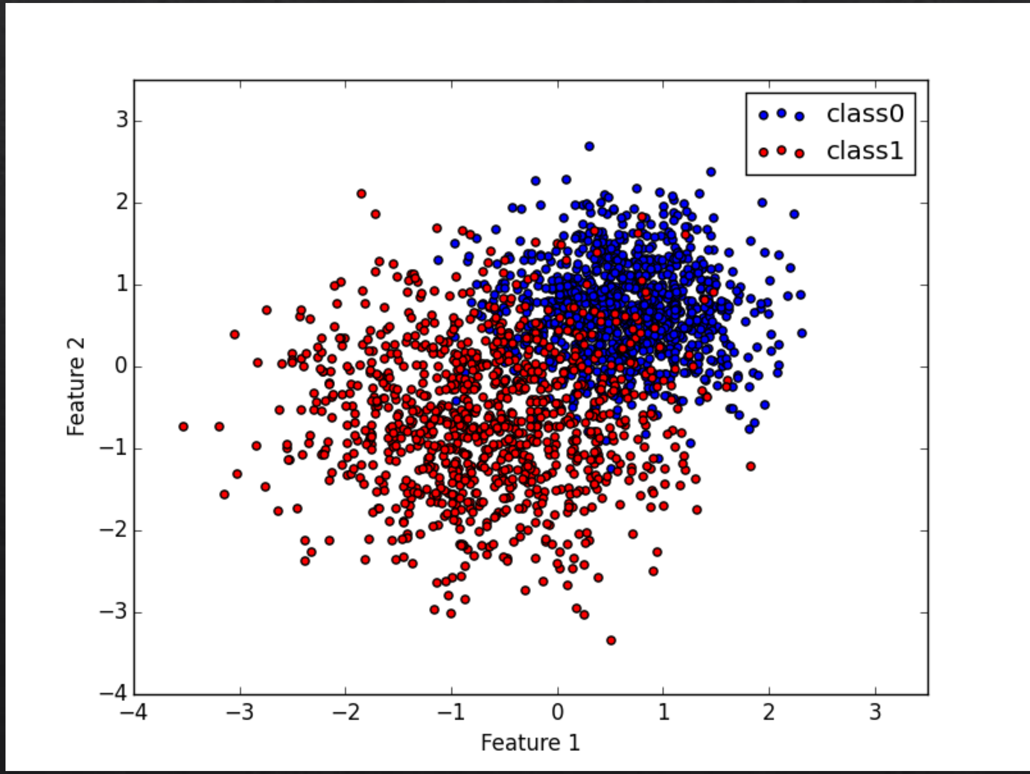

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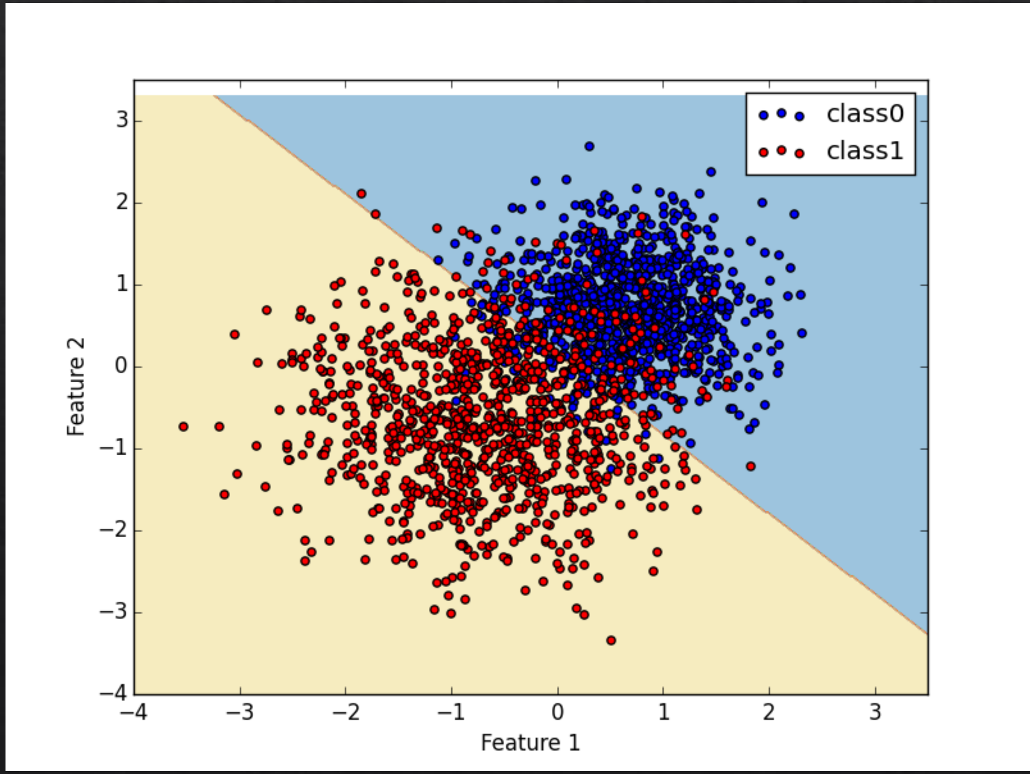

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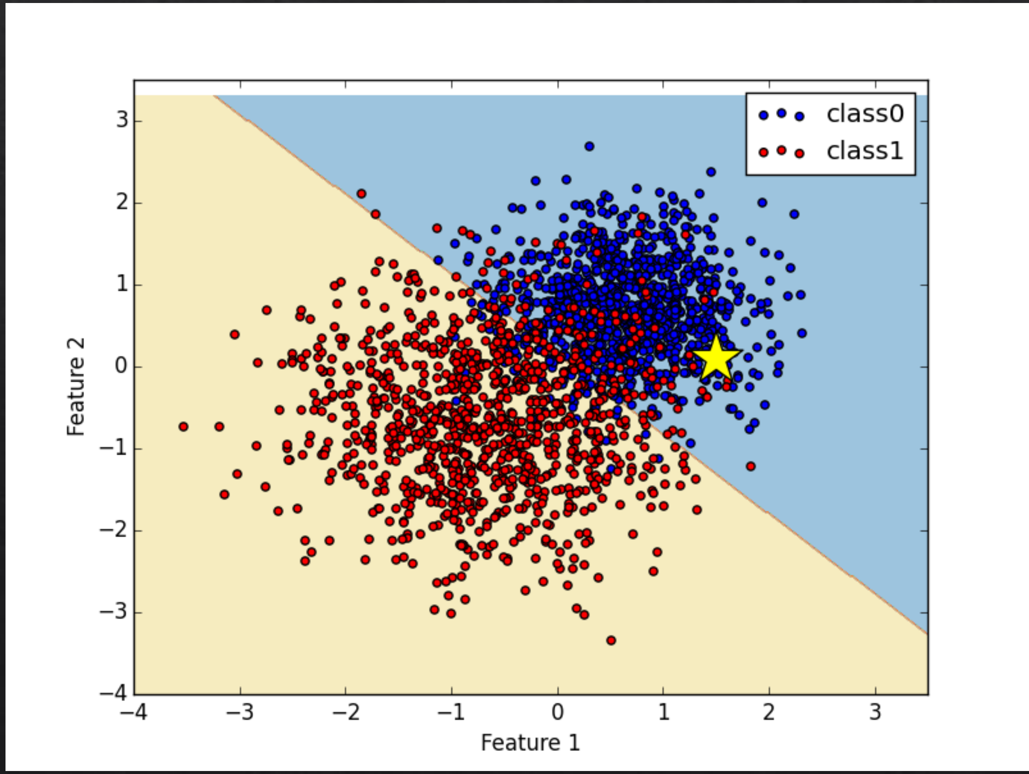


5. Control signal and feedback

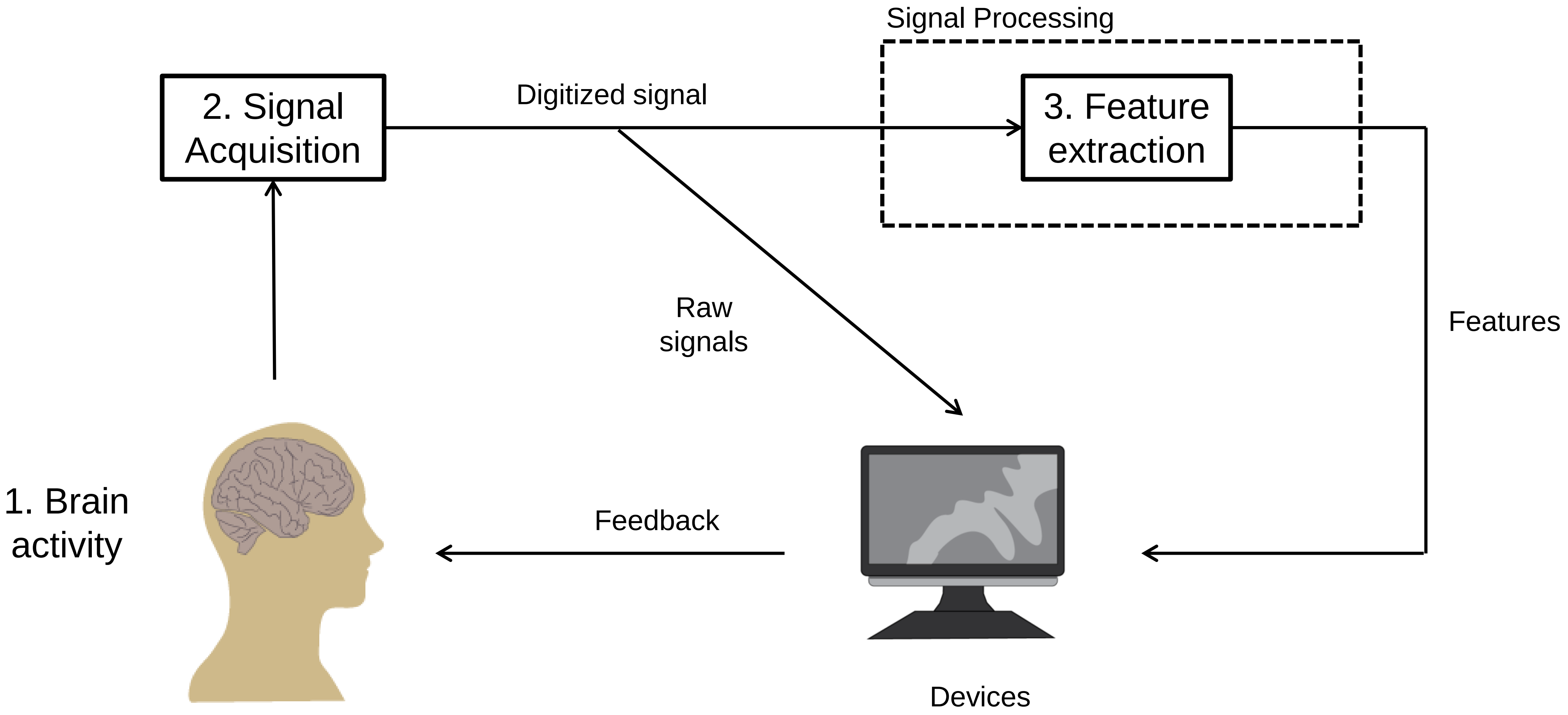
Hands-on exercises!

1. Installing and configuring the dependencies

Software	Use in the workshop
Python 2.7 + NumPy, matplotlib and scikit-learn	Design and programming of the BCI
Muse SDK	Muse-specific drivers for communicating with the Muse EEG headset via Bluetooth
MuLES (MuSAE Lab EEG Server)	Device-agnostic link between Python and the EEG drivers

Follow the instructions and the links provided in the **INSTRUCTIONS.md** document on github.com/bcimontreal/bci_workshop

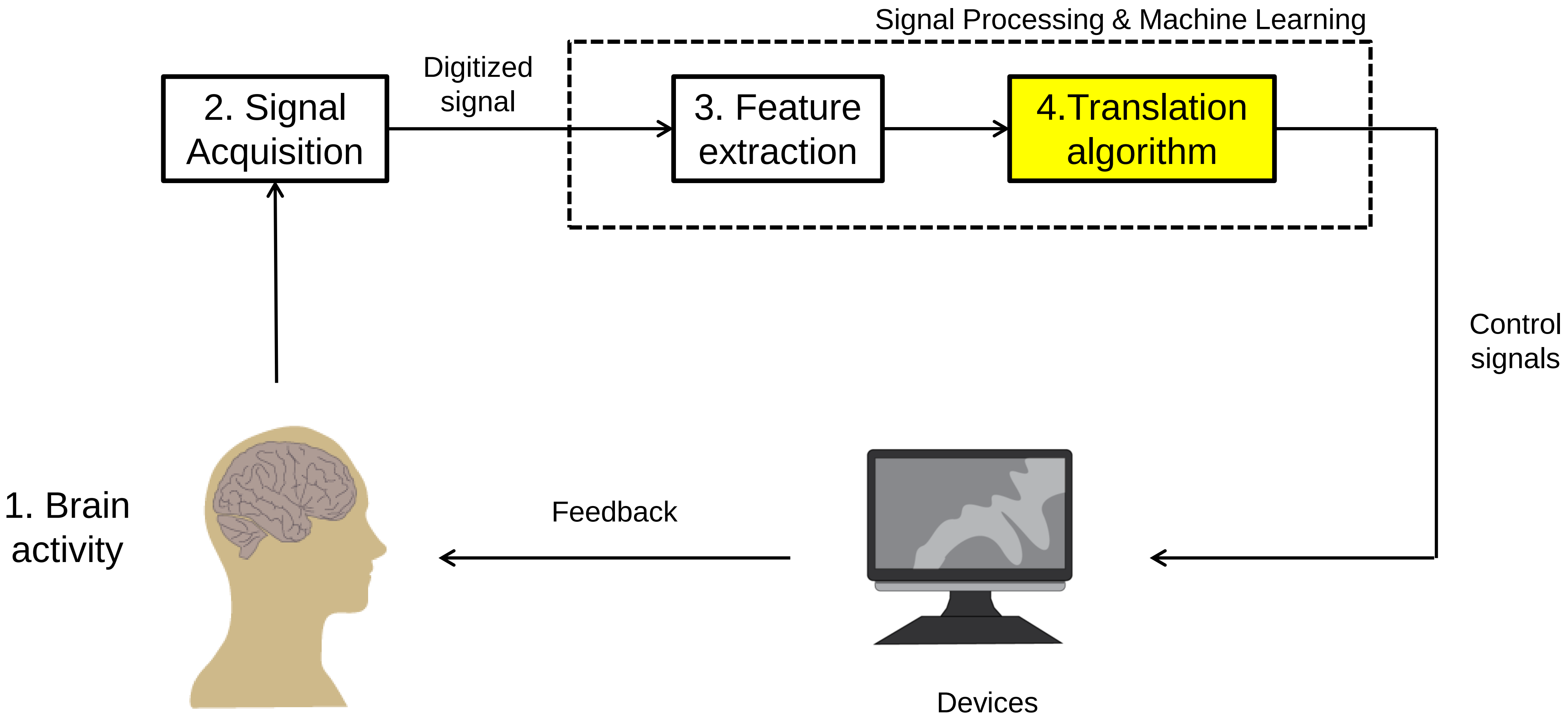
Exercise 1: A simple neurofeedback interface



Ex. 1: Quick demo

Ex. 1: Your turn!

Exercise 2: A basic BCI

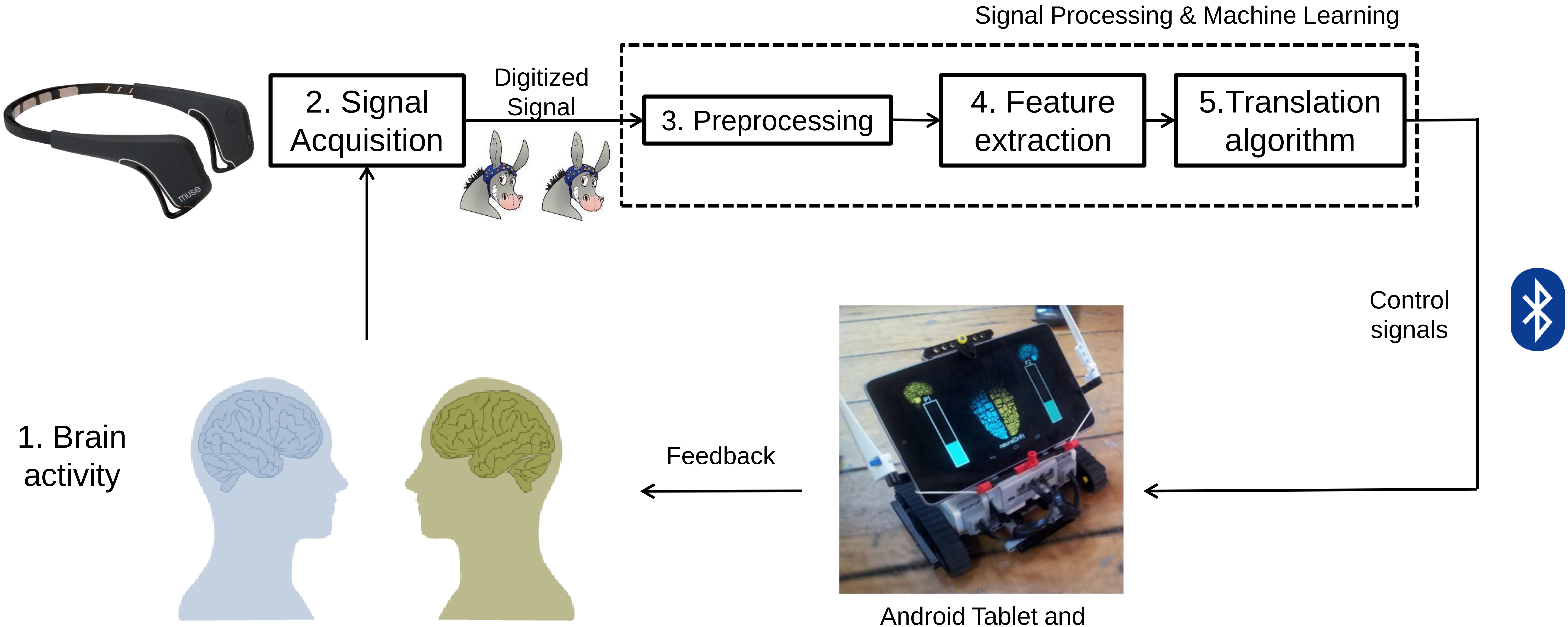


Ex. 2: Quick demo

Ex. 2: Your turn!

Going further…

neuralDrift:
A neurogame made during WearHacks 2014

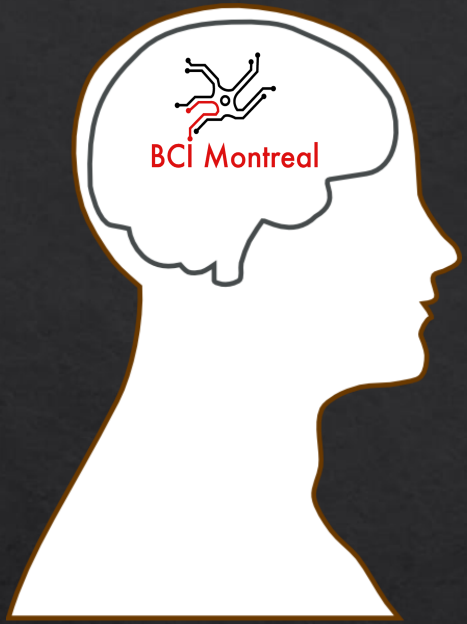


Android Tablet and LEGO robot

https://github.com/hubertjb/neuraldrift

Take-home messages

- Brain activity produces **electrical potentials** that we can measure with **EEG;**
- Some types of brain activity produce **stronger patterns** that we can use for controlling a BCI;
- We need to **extract features** from the raw EEG signals to get a clearer idea of what is happening in the brain;
- We use **machine learning** to classify brain activity based on calibration data.



Thank you!

Don’t forget to join our community on **Meetup**, **Facebook** and **Twitter**!

Any suggestions and comments are greatly appreciated
(unless it’s on the use of WordArt)!