

Bioengineering and Innovation in Neurosciences (BIN)

UE 3.7-8 Brain-computer interfaces: from modeling to engineering (6 ECTS)

- **Organizer** : François VIALATTE (ESPCI ParisTech)

***Abstract:** By the end of this teaching unit, students will be able to design a brain-computer interfaces (BCI) system by themselves. The purpose of the training unit is twofold: (i) to provide students with basic knowledge in statistics, signal processing and machine learning, which are ubiquitous tools for the modeling of complex systems such as the brain and neural systems, and (ii) to describe actual applications of the concepts presented in the first three courses, especially BCI. The first three courses mentioned below will present the methodological tools for designing valid data-driven models. **ESPCI students may be dispensed with part or all of course 3 (Machine learning), depending on their track record.** Courses 4 to 6 will describe applications to electroencephalographic modeling and BCI. Course 7 will describe the design of an innovative prosthetic device that generates an intelligible speech signal from the motion of the tongue and lips of laryngectomized patients (i.e. individuals who can articulate but lost their vocal chords due to cancer surgery). Course 8 will present applications of modeling to various aspects of the olfactory system. Course 9 will involve a personal project.*

***Prerequisites:** Minimal understanding mathematical concepts (what are variables and time series). Basic notions of programming (ideally with Matlab).*

***Evaluation:** 3 written exams + 1 oral exam (70%) + project reports/presentations (30%).*

***Recommended reading** (to prepare for and/ or accompany the courses):*

For those not familiar with programming and signal processing (e.g. students with a biomedical background), we **strongly** advised to check the introductory book of van Drongelen (c below).

- Nicolelis M., 2011, Beyond Boundaries: The New Neuroscience of Connecting Brains With Machines – And How It Will Change Our Lives, Times books.
- Buzsaki G., 2006, Rhythms of the brain, Oxford University Press.
- van Drongelen W., 2007, Signal processing for neuroscientists, Elsevier, Amsterdam.
- Apprentissage Statistique, G. Dreyfus et al. (Eyrolles, 2008)
- Neural Networks, G. Dreyfus (Springer, 2006).
- Probability with statistical applications, R. B. Schinazi (Birkhäuser, 2012).
- Probability and statistics for engineers and scientists, A. Hayter (Brooks/Cole, 2013).

- 1) *Signal processing in neuroengineering (François VIALATTE, ESPCI ParisTech) 4h course*
- 2) *Statistical hypothesis testing in biology (Isabelle RIVALS, ESPCI ParisTech) 3h course + 4h tutorials*
- 3) *Machine learning (François VIALATTE, ESPCI ParisTech) 6h course*
- 4) *Technological basics of EEG (Hovagim BAKARDJIAN, IHU A-ICM) 1h course*
- 5) *Brain-Computer Interfaces : costs and limits (François VIALATTE, ESPCI ParisTech) 1h course*
- 6) *Analyzing signal complexity and stationarity (Nesma HOUMANI, ESPCI ParisTech) 2h course*
- 7) *Application: a silent speech interface (Bruce DENBY, UPMC and ESPCI ParisTech) 2h course*
- 8) *Application: modeling the olfactory system (Pierre YGER, ENS) 3h course*
- 9) *personal BCI videogame project, developed using Matlab and OpenViBE (François VIALATTE, Nesma HOUMANI, Thierry GALLOPIN, ESPCI ParisTech) 32h project-based learning*

