Advanced Analysis of Neuronal Signals (22172)

Academic year 2013-14

1. Teaching activity identification

Advanced Analysis of Neural Data is a 4 ETCS optional subject from the Biomedical Engineering degree that will be taught during the second trimester of the 3rd course. The subject is divided in two parts, which will have special emphasis on the study of: 1) the theory of linear and nonlinear signal analysis and applications to electroencephalographic (EEG) recordings from epilepsy patients as well as 2) understanding the neural code and its relation to brain structure and function.

2. Coordination and teaching staff

The teaching activities of the first part of the subject will be coordinated by Ralph Gregor Andrzejak whereas the activities of the second half will be coordinated by Laura Dempere. The subject will be taught in English, but optionally Catalan and/or Spanish can be used as well.

3. Competences

a. Basic concepts of linear and nonlinear signal analysis.
b. The concept of null hypothesis testing by means of surrogate signals.
c. Applications of nonlinear signal analysis to the electrophysiological signals based on the example of electroencephalographic recordings of epilepsy patients.
d. Analysis of discrete spike trains and their relation with information encoding and decoding.
e. Understanding of the different levels of description of the neuronal systems and their relationship.

4. General objectives

The overall goal of the subject is to gain fundamental insights into brain function and structure from the perspective offered by a variety of neurophysiological measures. The different types of signals which will be considered in this course address the study of brain function at different scale levels, ranging from the single neuron level to the complete brain. Several methods will be studied, which specifically address the analysis of the different signal modalities considered for each level of description. The type of neuronal signals that will be considered include discrete spike trains, continuous EEG signals, and structural neuroimages. The students are expected to gain a fundamental understanding into the concepts and methods presented during the course rather than just memorize details. This is why hands-on practical work will be central to this course. Such type of activities will provide the student with opportunities to manipulate real data and apply the learned methods.

5. Teaching methodology

All the teaching activities have been developed to promote both a critical thinking by the students and their active participation in the class-room.

The proposed teaching activities are as follows:

5.1 Lectures
The lecturer will present the main theoretical contents and will promote subsequent discussions by the group. Graphic support will be used in the lectures in the form of slides, videos and matlab simulations, which will be published on Aula Global.

5.2 Seminars and *Practical work*
Seminars and hands-on practical work will complement some of the topics learned in the theoretical classes. In these sessions, the students will gain further insight into the main concepts and methods studied in the lectures by addressing practical problems in neuroscience. To this end, the students will make use and/or write their own scripts in Matlab to perform the computational analysis of real neuronal data.

6. Course Program (4 ECTS)

6.1 Revision of fundamental types of dynamics
Deterministic dynamics
Stochastic dynamics

6.2 Linear and nonlinear signal analysis
Power spectrum and autocorrelation
Nonlinear prediction error
The concept of surrogate time series

6.3 Application to EEG recordings of epilepsy patients
Epilepsy and intracranial EEG recordings in epilepsy patients
The epileptic focus
Localizing the epileptic focus with nonlinear signal analysis techniques

6.4 Neural encoding and decoding
Firing rates and spike statistics
Neuronal encoding tuning curves
Spatiotemporal filtering and reverse correlation
Signal detection theory
Population decoding

6.5 Brain structure and function: a neuroimaging perspective
From single neurons to large-scale models: an overview
Functional connectivity
Diffusion tensor imaging
Co-registration of brain images
Atlases of morphology and functional anatomy of the brain

7 Evaluation

PART 1. Non-linear time series analysis of continuous EEG recordings

- **Practical sessions** (100% of final mark Part 1). The students have to submit two or three assignments. Attendance to the practical sessions and on-time submission of the corresponding reports are compulsory.

PART 2. The neural code and its relation to brain structure and function

- **Practical sessions** (50% of final mark Part 2). The students must submit two assignments. Attendance to the practical sessions and on-time submission of the corresponding reports are compulsory.

- **Theoretical content***s* (50% of final mark Part 2). The students will sit a written exam at the end of the course, which will include short questions related to the concepts studied in the lectures, seminars and practical sessions.

COMPLETE COURSE

Final grade = (Grade Part 1 + Grade Part 2) / 2