Master degree 2, Mathematics & Applications
MASC
(Modeling & Analysis of Complex Systems)

Dynamical Systems & Deterministic Modeling

Learning Objectives:

We first propose to give the basic elements to understand the biological mechanisms leading to the electrical behavior of a neuron, and to the development of the main mathematical models in neuroscience. A neuron can present rich dynamic behaviors, such as periodic spiking, bursting or even chaos. In order to study these behaviors, we will present some methods permitting to determine all the periodic solutions of a nonlinear dynamical system. We will finish this course by describing identification methods of continuous time parametric models from sampled data. These methods will be applied to classical models describing the neuron behavior.

Prerequisites :

Master 1 ODE course, linear algebra, numerical methods, computation in Scilab, C or other language.

Detailed Description of the Course :

1. Deterministic models in neuroscience
- Neurons biology – The basics
- The Hodgkin-Huxley model & the FitzHugh-Nagumo model
- Neurons biology – Supplements
- More detailed mathematical models

2. Periodicity study
-Periodic solutions (definitions, existence conditions, …)
-Lur'e systems
-Harmonic balance method and descriptive function technique
-Application to the FitzHugh-Nagumo model

3. Identifiability and parameters estimation
- Parametric models, identifiability, parametric sensitivity
- Definition and choice of criteria to estimate parameters
- Classical methods for parameter estimation
- Application to the Hodgkin-Huxley and the FitzHugh-Nagumo models

Textbooks & Further Reading :

1. Ermentrout, G. B., & Terman, D. H. (2010). *Mathematical foundations of neuroscience* (Vol. 35). Springer Science & Business Media.
2. Mees, A. I. (1981). *Dynamics of feedback systems*. John Wiley & Sons, Inc.
3. Tarantola, A. (2005). *Inverse Problem Theory and methods for model Parameter Estimation*, SIAM.
4. Walter, E., & Pronzato, L. (1997). *Identification of Parametric Models from Experimental Data*, Springer-Verlag, Berlin.