Subject identification

Subject	11300 - Mathematical Models in Neuroscience
Credits	0.96 de presencials (24 hours) 2.04 de no presencials (51 hours) 3 de totals (75 hours).
Group	Group 1, 2S (Campus Extens)
Teaching period	Second semester
Teaching language	English

Professors

Lecturers	**Horari d'atenció als alumnes**					
	Starting time	**Finishing time**	**Day**	**Start date**	**Finish date**	**Office**
Antonio Esteban Teruel Aguilar	15:30	17:30	Thursday	08/02/2016	31/07/2016	D-120
antonioe.teruel@uib.es	10:30	11:30	Tuesday	08/02/2016	31/07/2016	D-120

Contextualisation

Much of present neuroscience research concerns voltage- and second-messenger-gated currents in individual cells, with the goal of understanding the cell's intrinsic neurocomputational properties. It is widely accepted that knowing the currents suffices to determine what the cell is doing and why it is doing it. This, however, contradicts a half-century–old observation that cells having similar currents can nevertheless exhibit quite different dynamics. This observation was largely ignored by the neuroscience community until the seminal paper by Rinzel and Ermentrout (1989), who showed that the difference in behavior is due to different bifurcation mechanisms of excitability.

In this course we present an introductory study of the relationship between electrophysiology, bifurcations, and computational properties of neurons, where we will learn why cells having nearly identical currents may undergo distinct bifurcations, and hence they will have fundamentally different neurocomputational properties. Conversely, cells having quite different currents may undergo identical bifurcations, and hence they will have similar neurocomputational properties.

Since Ordinary Differential Equations is the language of a big amount of computational neuroscience research, some issues on qualitative theory will be introduced and complemented with simulations on XPPAUT and MAXIMA of various neural models.

I am part of an international research group in the field of neuroscience which is aimed to model the different behaviors exhibited by neurons by using differential equations. Consequently, my professional profile fits perfectly to the contents of this course.

Requirements

Recommendable

It is advisable to have knowledge about qualitative theory of ODEs or to study also the master subjects:

* Introduction to dynamic systems
* Techniques in the study of periodic solutions of ODEs

Skills

Specific

* CE1 That students have the learning skills to allow them to combine an specialized training in Astrophysics and Relativity, Geo-physical Fluids, Materials Physics, Quantum Systems or Applied Mathematics, with the versatility which provides an open curriculum..
* CE2 Students must possess the ability to use and adapt mathematical models to describe physical phenomena of different nature..
* CEMA2 In the field of neuroscience and images, to develop the ability to identify and describe a problem mathematically, to structure the information available and to select an appropriate mathematical model for resolution..
* CEMA3 Ability to relate the theory of dynamical systems with applications in different fields covered: mechanics, circuit theory, neuroscience..

Generic

* CG1 Systematic understanding of a field of study and mastery of the skills and methods of research associated with that field..

Basic

* You may consult the basic competencies students will have to achieve by the end of the Master's degree at the following address: http://estudis.uib.cat/master/comp_basiques/

Content

Theme content

Theme 1. Introduction

In this theme we present neurons as dynamical systems: resting state of neurons corresponds to a stable equilibrium; the tonic spiking state corresponds to a limit cycle attractor and excitability of neurons corresponds to equilibrium state near a bifurcation.

Theme 2. Electrophysiology of Neurons

Electrical signals in neurons are carried by $Na+$, $Ca2+$, $K+$, and $Cl-$ ions, which move through membrane channels according to their electrochemical gradients. The membrane potential is then determined by the membrane conductances and corresponding reversal potentials. In this theme we present the most accepted description of kinetics of voltage-sensitive conductances, namely the Hodgkin-Huxley gate mode. Besides, we also present a characteristic behaviour, the action potential or spike as a brief regenerative depolarization of the membrane potential followed by its repolarization and possibly hyperpolarization.

Theme 3. Conductance-Based Models and Their Reductions

We introduce the minimal model to exhibit excitability. Many models can be reduced to two-dimensional systems with one equation for voltage and instantaneous amplifying currents, and one equation for a resonant gating variable. The behavior of a two-dimensional model depends on the position of its nullclines. Many models have an cubic-shaped nullcline and a sigmoid-shaped nullcline for the gating variable. Quite different electrophysiological models can have similar nullclines, and hence essentially the same dynamics.

The spike generation mechanism of detailed electrophysiological models depends on the dynamics near the left knee of the fast nullcline, and it can be captured by a simple model.

Theme 4. Bifurcations and neuronal excitability

In this theme we provide definitions and examples of all codimension-1 bifurcations (depending on a one dimensional parameter) of an equilibrium and a limit cycle that can occur in two-dimensional systems. We also mention some codimension-1 bifurcations in high-dimensional systems, as well as some codimension-2 bifurcations. We finally discuss how the type of bifurcation determines a cell's neurocomputational properties.

Theme 5. Simplest models

In this theme we review salient features of cortical, thalamic, hippocampal, and other neurons, and we present simple models that capture the essence of their behavior from the dynamical systems point of view.

Teaching methodology

In-class work activities

Modality	Name	Typ. Grp.	Description	Hours
Theory classes	Theory class	Large group (G)	Exhibition in master classes of the content presented on the table of content.	15
Laboratory classes	Computer room.	Medium group (M)	Introduction of the usual simulation tools in neuroscience, XPPAUTO, and in the symbolic manipulation WXMAXIMA. With these tools we illustrate some of the exemples presented in the theory classes.	6
Assessment	Exposition of the works.	Large group (G)	The student will present the contents of a previously assigned work.	3

At the beginning of the semester a schedule of the subject will be made available to students through the UIBdigital platform. The schedule shall at least include the dates when the continuing assessment tests will be conducted and the hand-in dates for the assignments. In addition, the lecturer shall inform students as to whether the subject work plan will be carried out through the schedule or through another way included in the Campus Extens platform.

Distance education work activities

Modality	Name	Description	Hours
Individual self-study	Assigned problems	The student must make a list of the problems that subsequently delivered for evaluation.	51

Specific risks and protective measures

The learning activities of this course do not entail specific health or safety risks for the students and therefore no special protective measures are needed.

Student learning assessment

Exposition of the works.

Modality	Assessment
Technique	Papers and projects **(retrievable)**
Description	The student will present the contents of a previously assigned work.
Assessment criteria	The student will submit a report of the work that the teacher will evaluate. This note will be complemented by observation techniques and questions during the exhibition. CE1,CE2,CEMA1,CEMA2,CG1.

Final grade percentage: 50%

Assigned problems

Modality	Individual self-study
Technique	Papers and projects **(retrievable)**
Description	The student must make a list of the problems that subsequently delivered for evaluation.
Assessment criteria	Objective evaluation of the solutions of a list of assigned problems. CE1,CE2,CEMA1.

Final grade percentage: 50%

Resources, bibliography and additional documentation

Basic bibliography

* Eugene M. Izhikevich. Dynamical systems in neuroscience : the geometry of excitability and bursting. Computational neuroscience. MIT, Press, 2007.
* Lawrence Perko. Differential equations and dynamical systems 3rd. ed. Springer. 2001.

Other resources

Materials designed by the teacher and available on the website of the course.