COURSE GUIDE: Neuroinformatics (NEI)

Academic year: 2015-2016

Program: Master's program in Research and Innovation in Information and Communications Technologies (I^2-ICT)
Center: Escuela Politécnica Superior
University: Universidad Autónoma de Madrid

Last modified: 2015/05/19
Status: Approved June 8th 2015

1. NEUROINFORMATICS / NEI

Neuroinformática
Neruoinformatics (NEI)

1.1. Programa / program

Máster Universitario en Investigación e Innovación en Tecnologías de la Información y las Comunicaciones (I^2-TIC)

Master in Research and Innovation in Information and Communications Technologies (I^2-ICT) [Officially certified]

1.2. Course code

32425

1.3. Course areas

Computer Science and Artificial Intelligence

1.4. Tipo de asignatura / Course type

Optativa [itinerario: Informática Biomédica]
Elective [itinerary: Biomedical Informatics]

1.5. Semester

First semester

1.6. Credits

6 ETCS

1.7. Language of instruction

The lecture notes are in English. The lectures will be in Spanish or English according to the students' requests.

1.8. Recommendations / Related subjects

Related subjects are:

- Procesamiento de señales biomédicas y sus aplicaciones [Biomedical signal processing and its applications]
- Boidispositivos [Biodevices]
- Caracterización de redes y topologías biológicas [Characterization of biological networks and topologies]
- Computación Bioinspirada [Bio-inspired computing]
- Procesamiento de imágenes biomédicas y sus aplicaciones [Biomedical image processing and its applications]
- Sistemas de información en biomedicina: integración y gestión del conocimiento [Information systems in biomedicine: integration and knowledge management]

1.9. Lecturers

Add @uam.es to all email addresses below.

Lectures and labs:

Dr. Pablo Varona (Coordinator)
Departamento de Ingeniería Informática
Escuela Politécnica Superior
Office: B-330
Tel.: +34 914972263
e-mail: pablo.varona
Web: http://www.eps.uam.es/~pvarona

Dr. Eduardo Serrano
Departamento de Ingeniería Informática
Escuela Politécnica Superior
Office: B-304
Tel.: +34 914972238
e-mail: eduardo.serrano
Web: http://www.eps.uam.es/~eserrano

Dr. Francisco de Borja Rodríguez
Departamento de Ingeniería Informática
Escuela Politécnica Superior
Office: B-328
Tel.: +34 914972236
e-mail: f.rodriguez@uam.es
Web: http://www.eps.uam.es/~gnb

1.10. Objetivos de la asignatura / Course objectives

En esta asignatura se describe el sistema nervioso desde el punto de vista de su funcionalidad: el procesamiento de información. Esta perspectiva complementa el estudio tradicional basado en una descripción morfológica y fisiológica. Para ello, se hace uso de modelos de neuronas y redes neuronales en distintas escalas de descripción: desde los modelos biofísicos de membrana conductiva a paradigmas de descripción abstracta que se utilizan para describir fenómenos en la actividad de grandes redes. En esta asignatura se enfatiza el papel de la dinámica intrínseca de las neuronas, de la conectividad, del aprendizaje, y de la dinámica colectiva de red. Se proponen también varios formalismos teóricos para la descripción de la codificación, aprendizaje y ejecución de información neuronal. Esta perspectiva contribuye al entendimiento del funcionamiento del sistema nervioso y al estudio de varios tipos de enfermedades neurodegenerativas como la epilepsia, el Parkinson y la esclerosis.

This course describes the nervous system from the perspective of its functionality: information processing. This perspective complements traditional studies based on morphological and physiological descriptions. Models of neurons and neural networks are studied at different description levels: from conductance-based biophysical paradigms to abstract models used in large population networks. In this course we emphasize the role of intrinsic neuronal dynamics, the connectivity, the learning mechanisms and the overall network dynamics. Several theoretical formalisms to describe coding, learning and information execution are explained. The models are used to provide further insight on the nervous system and to study several types of neurodegenerative diseases such as epilepsy, Parkinson's disease and multiple sclerosis.

At the end of each unit, the student should be able to:

UNIT BY UNIT SPECIFIC OBJECTIVES	
UNIT 1.- Introduction to Computational Neuroscience	
1.1.	Describe the fundamental morphological and physiological components of the nervous system
1.2.	Characterize different levels of neural information processing
1.3.	List the scales and strategies in neural modeling
UNIT 2.- Single neuron modeling	
2.1.	Characterize, implement and analyze conductance based models
2.2.	Characterize, implement and analyze simplified dynamical models and integrate & fire models
2.3.	Characterize, implement and analyze rate models
UNIT 3.- Dynamical analysis of neural models	
3.1.	Understand nonlinear Dynamical Systems in one and two dimensions: bifurcations and phase plane analysis
3.2.	Summarize the use of dynamical systems theory in modeling in neuroscience
3.3.	Reduce a Hodgkin-Huxley model to a one, two and three dimensional model

3.4.	Understand how different types of bifurcations determine the computational properties of neurons
3.5.	Discuss how such dynamical systems approaches can lead to the design and analysis of simple electro-physiological experiments
UNIT 3.- Connectivity models. Learning and plasticity	
4.1.	Implement chemical, graded and gap junction synapses.
4.2.	Characterize the different synaptic plasticity and learning paradigms.
4.3.	Distinguish between synaptic and subcellular learning paradigms.
UNIT 5.- Stochastic neural models	
5.1.	Understand the motivation for stochastic neural models
5.2.	Characterize and implement stochastic neural models
5.3.	Analyze stochastic network models
UNIT 6.- Neural network dynamics and codes	
6.1.	Characterize and use theoretical formalisms to describe neural network dynamics in sensory, motor and central nervous systems
6.2.	Characterize the different neural codes for information processing
UNIT 7.- Medical neuroinformatics	
7.1.	Characterize different diseases in the nervous system in terms of information processing malfunctions
7.2.	Build and analyze models of Epilepsy, Parkinson and Multiple Sclerosis

1.11. Course contents

1. Introduction to Computational Neuroscience
    a. Fundamentals of Neuroscience
    b. Introduction to neural information processing
    c. Scales and strategies in neural modeling

2. Single neuron modeling
    a. Conductance based-models
        i. Hodgkin-Huxley models
        ii. Multicompartmental models
    b. Simplified dynamical models and Integrate & Fire models
    c. Rate models

3. Dynamical analysis of neural models
    a. Phase plane analysis
    b. Bifurcations
    c. Model dimension reduction
    d. Neuronal excitability

4. Connectivity models. Learning and plasticity
    a. Chemical synapses.

   b. Graded synapses
   c. Gap junctions.
   d. Synaptic plasticity and learning.
   e. Subcellular learning

5. Stochastic neural models
   a. Motivation for stochasticity in neural models
   b. How to include the stochasticity in neural models
   c. Examples of stochastic neural models

6. Neural network dynamics and codes
   a. Motor systems
   b. Sensory systems
   c. Central nervous system

7. Medical neuroinformatics
   a. Epilepsy models
   b. Parkinson models
   c. Multiple sclerosis models

1.12. Course bibliography

1. Fundamentals of Computational Neuroscience, Thomas P. Trappenberg. Oxford University Press, 2nd edition, 2011.
2. Principles of Computational Modelling in Neuroscience, David Sterratt, Cambridge, 2011. Pdf de prueba del autor.
3. Methods in Neuronal Modeling: From Ions to Networks, edited by Christof Koch and Idan Segev 2-nd edition. MIT Press, Cambridge, MA, 2003.
4. Biophysics of Computation. Information Processing in Single Neurons. C. Koch. Oxford University Press: New York, Oxford, 2004.
5. Principles of Brain Dynamics: Global state interactions. M.I. Rabinovich, K.J. Friston, P. Varona. Eds. MIT Press, 2012
6. Dynamical Systems in Neuroscience. E.M. Izhikevich. MIT Press, 2007.
7. Spiking Neuron Models. W. Gerstner, WM. Kistler. Cambridge University Press, 2002.
8. Theoretical Neuroscience Computational and Mathematical Modeling of Neural Systems. Peter Dayan and LF Abbott. MIT 2005.
9. Spikes, decisions and actions. The dynamical foundations of neuroscience. H.R. Wilson. Oxford University Press, 1999.
10. Bursting: The Genesis of Rhythm in the Nervous System. S Coombes and P.C. Bressloff. World Scientific, 2005.

11. Diversity in the Neuronal Machine: Order and Variability in Interneuronal Microcircuits. I. Soltesz. Oxford University Press, 2005.
12. Microcircuits: The Interface between Neurons and Global Brain Function. S. Grillner, A.M. Graybiel (Editors). The MIT Press, 2006.
13. Problems in Systems Neuroscience. J. Leo van Hemmen, Terrence J. Sejnowski (Editors). Oxford University Press, 2005.
14. E. R. Kandel, J. H. Schwartz, T. M. Jessel; Principles of Neural Science. 5th Edition, Prentice Hall, London, 2012.

1.13. Coursework and evaluation

The course involves lectures, weekly assignments, lab assignments, a seminar presentation and one exam.

In both the ordinary and the extraordinary exam period it is necessary to achieve a pass grade (≥ 5) in each of these assessments to pass the course.

- In the ordinary exam period, the evaluation will be made according to the following scheme
  - 20 % Exercises and class participation
  - 20 % Lab assignments
  - 35 % Seminar presentation on a research topic in neuroinformatics
  - 25 % Exam

- In case of a fail grade, the student has the opportunity to
  - Turn in all the exercises with corrections
  - Turn in all the lab assignments with corrections.

All assessments are mandatory both in in the ordinary and extraordinary evaluation periods.