upf. Barcelona Program for Interdisciplinary Studies

BaPIS
Winter 26

Course title: Mind, Brain and Machines
Language of instruction: English
Professor: Jordi Garcia Ojalvo and Fernando Giráldez
Professor's contact and office hours:

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Office hours on demand

Course contact hours: 45
Recommended credit: 6 ECTS credits
Course prerequisites: There are no prerequisites for this course
Language requirements: Recommended level in the European Framework B2 (or equivalent : Cambridge Certificate if the teaching language is English, DELE or 3 semesters in the case of Spanish).

Course focus and approach:
This course aims at providing an interdisciplinary view of intelligence, grounded on the understanding the human brain provided by neuroscience and artificial intelligence. Neuroscience and engineering study the brain or artificial forms of brain function. This knowledge has strong implications in many areas of human activity including not only medicine, psychology, computer engineering, robotics, and data analysis, but also economics, law, philosophy or art.

Course description:
What do we talk about when we discuss artificial intelligence? This class explores the connections between artificial intelligence and brain sciences. We delve into how brains and machines build up knowledge. A review of the history of artificial intelligence and the neurosciences will reveal the evolving ties between these two fields. With a focus on vision, we will simultaneously explore the fundamental requirements of a brain, building upon the quest to create intelligent systems and learning machines. Ultimately, we shall engage in an in-depth discussion on the foundations and constraints of knowledge and belief.

Learning objectives:
By the end of the course, the student will be:

- describe the basic elements of the brain: genes, neurons, synapses and circuits, and have an intuitive understanding of the operation of neural networks
- familiar with the general principles of organization of the sensory systems and perception.
- able to apply neuroscientific knowledge in diferent scrintific contexts.
- acquainted with the evolutionary roots of perception and behavior.
- able to describe the interactions between genes and environment.
- familiar with the history of artificial intelligence, and with its connections with the study of the human brain

- will be able to hypothesize about the minimal fundamental mechanisms for a brain to function

Course workload:
The course is based on discussion sessions, class exercises, and lectures. Students will read short articles (two-three pages), fragments or book chapters and write short papers/reports (one page) along the course. Students will do a ten-minute oral presentation to the class. There will be a mid-term and a final exam.

Teaching methodology:
The class will combine a set of lectures and seminars with activities based on active learning. Lectures are intercalated with discussion sessions. Materials, presentations, handouts, and readings will be available through the Aula Global. Demonstrations include animations and interactive materials. It is expected that students contribute with their own background to discussions and works.

Assessment criteria:
- Midterm exam (MT): 25%
- Final exam: 25%
- Class participation: 20%
- Project/paper presentation (*chalk-talk*): 30%

The Final exam consists of two parts, one corresponding to sessions 1-10 (MT exam), and the second corresponding to sessions 12-15. Students may recover or improve your MT exam at the Final Exam (we'll always keep the best mark). Class participation box can be filled with different activities, including session assignments and active participation.

BaPIS absence policy:
Attending class is mandatory and will be monitored daily by professors. Missing classes will impact on the student's final grade as follows:

Absences	**Penalization**
Up to two (2) absences	No penalization
Three (3) absences	1 point subtracted from final grade (on a 10-point scale)
Four (4) absences	2 points subtracted from final grade (on a 10-point scale)
Five (5) absences or more	The student receives an INCOMPLETE ("NO PRESENTADO") for the course

The BaPIS attendance policy does not make a distinction between justified and unjustified absences. All absences—whether due to common short-term illnesses or personal reasons—are counted toward the total amount and cannot be excused. Therefore, students are responsible for managing all their absences.

Only in cases of longer absences—such as hospitalization, prolonged illness, traumatic events, or other exceptional situations—will absences be considered for exceptions with appropriate documentation. The Academic Director will review these cases on an individual basis.

Students must inform the Instructor and the International Programs Office promptly via email if serious circumstances arise.

Classroom norms:

- No food or drink is permitted in class.
- Students will have a ten-minute break after each one-hour session.

Weekly schedule:

WEEK 1
Session 01 Welcome and Introduction to the course
WEEK 2
Session 02 A brief history of thinking machines. The nature of artificial brains. Approaches to artificial intelligence (AI). The timeline of AI.
Session 03 The synapse and neural circuits: how the brain computes Elementary synaptic circuits: gates, lateral inhibition, feed-back and forward loops in real life.
WEEK 3
Session 04 The mechanization of thought. Early approaches to logic: from Aristotle to Llull. The laws of thought: from Boole to Turing.
Session 05 The Allegory of the Cave and the Neurosciences. The logics of perception: the representation of the world. Where are concepts in the brain?
WEEK 4
Session 06 The symbolist approach to AI. Tree search and heuristics: Newell and Simon's Logic Theorist. The General Problem Solver.
Session 07 The retina as a multiple feature detector: what the retina tells the brain.
WEEK 5
Session 08 Knowledge representation. Expert systems. Beliefs, uncertainty, and Bayesian networks.
Session 09 The visual cortex as a biological perceptron: Faces and objects in the brain.
WEEK 6
Session 10 The early connectionist approach to AI. Neurons as logic elements: the McCulloch-Pitts model. Neurons and pattern recognition: the perceptron.
Session 11: Mid-Term exam (sessions 1-10)
WEEK 7
Session 12: The learning revolution. Multilayer networks. Supervised, unsupervised and reinforcement learning.

Session 13: How do we learn? What is learning. How neurons learn and how the brain learns.
WEEK 8
Session 14: Dynamics of thought. Generative AI and recurrent networks.
Session 15: Nature and Nurture. Genes and the brain: a false dilemma.
Session 16: Course project
WEEK 9
Session 17: Chalk talks / student presentations
Session 18: Chalk talks / student presentations
WEEK 10
Session 19: Chalk talks / student presentations
WEEK 11
Session 20: General discussion on Brain and Machines
Session 21: Final Exam

Last revision: March 2025

Readings:
Kandel, E. (2013a) Perception and Sensory Coding in Principles of Neural Science. Chapter 56: pp 445-474 McGraw-Hill Education

Kandel, E. (2013b) Experience and the Refinement of synaptic connections in Principles of Neural Science. Chapter 56 pp 1259-1283, McGraw-Hill Education

Minsky, M. (1986). *The society of mind*. Simon & Schuster

Nilsson, N. J. (2009). *The quest for artificial intelligence*. Cambridge University Press.

Vilis, T. (2020): The Physiology of the Senses http://www.tutis.ca/Senses/index.htm

von Neumann, J. (1958). *The computer and the brain*. Yale University Press.

Wolfe et al. (2017) Sensation and Perception (5th Ed.) chapter 6, Monocular cues to three- dimensional space pp 178-190

Links of interest:
BrainFacts.org: https://www.brainfacts.org an educational page by the Society for Neurosciences with many interesting posts, a useful glossary, and a basic "textbook"
Aeon: https://aeon.co An interesting site for the "Third Culture" and challenging ideas