Course title: Mind, Brain and Machines
Language of instruction: English
Professor: Fernando Giráldez and Jordi Garcia Ojalvo
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: None

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. The course focuses on a solid dialogue between neurosciences and humanities (see Giraldez, 2020 Teaching Neuroscience as a Liberal Art, Front. Educ. 4:158).

Course description:
This course centers on the interaction between Neurosciences, Engineering and the Humanities, by posing crucial questions on intelligence, perception and aesthetics. How brains and machines build up knowledge? What is intelligence and "what do we talk about when we talk about artificial intelligence"? We will analyze how sensory systems build up a representation of the world, with particular attention to vision and audition. In parallel, we will explore the minimal requirements of a brain, building on our age-old attempts to build artificial intelligent systems. We will review the history of artificial intelligence and brain science, focusing on the connections that the two fields have had, on and off, over the years. This leads to a more general discussion on the foundations and limits of knowledge and the evolutionary roots of belief. Can we gather reliable knowledge? Are we prone to believe? What is the relationship between genes and environment? Beyond that, how does biology conditions our experience of Art? And further, can computers mimic creativity in Art? The course attempts to frame the above questions into the current scientific knowledge of the brain and the engineering of complex systems.

Learning objectives:
By the end of the course, the student
- will be able to describe the basic elements of the brain: genes, neurons, synapses and circuits, and have an intuitive understanding of the operation of neural networks

- will be familiar with the general principles of organization of the sensory systems and perception, and will know why perception is said to be a constructive process
- will be able to apply neuroscientific knowledge to art perception and the rules of art
- will be acquainted with the evolutionary roots of perception and behavior
- will be able to describe the interactions between genes and environment, and frame discussion on the nature vs. nurture question into current scientific knowledge.
- will be 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 course will combine a set of lectures and seminars with activities based on flipped classroom. 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%

Exams are open-book.
You can 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 distinguish between justified or unjustified absences**. The student is deemed responsible to manage his/her absences.

Only absences for medical reasons will be considered justified absences. The student is deemed responsible to provide the necessary documentation. Other emergency situations will be analyzed on a case-by-case basis by the Academic Director of the BaPIS.

The Instructor, the Academic Director and the Study Abroad Office should be informed by email without any delay.

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: The history of the Brain
The biology of the brain. How the brain works. The biological history of the brain.
Session 02 A brief history of thinking machines. The nature of artificial brains. Approaches to artificial intelligence (AI). The timeline of AI.

WEEK 2:
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.
Session 04 The mechanization of thought. Early approaches to logic: from Aristotle to Llull. The laws of thought: from Boole to Turing.

WEEK 3:
Session 05 The Allegory of the Cave and the Neurosciences. The logics of perception: the representation of the world. What are ideas made of? Where are concepts in the brain?
Session 06 The symbolist approach to AI. Tree search and heuristics: Newell and Simon's Logic Theorist. The General Problem Solver.

WEEK 4:
Session 07 How do we see? Vision, from the retina to the brain
Session 08 The early connectionist approach to AI. Neurons as logic elements: the McCulloch-Pitts model. Neurons and pattern recognition: the perceptron.

WEEK 5:
Session 09 How do we hear? Hearing, from hair cells to ecstasy
Session 10 Knowledge representation. Expert systems. Beliefs, uncertainty, and Bayesian networks.

WEEK 6:
Session 11: Mid-term exam (sessions 1-10)

Session 12: Nature and Nurture (I): How we learn. What is learning, what is in the brain before learning? "Critical periods"

WEEK 7:
Session 13: The comeback of neural networks. Deep multilayer networks.
Session 14: Nature and Nurture (II): Genes and the brain. The concept of gene expression and the false dilemma of *nature or nurture*.

WEEK 8:
Session 15: The learning revolution. Supervised and unsupervised learning in neural networks. Reinforcement learning. Deep learning.
Session 16: Dynamics of thought. Recurrent networks and reservoir computing.

WEEK 9:
Session 17: General discussion on Brain and Machines
Session 18: Chalk talks / student presentations

WEEK 10:
Session 19: Chalk talks / student presentations
Session 20: Final Exam

The Final exam consists of two parts, one corresponding to sessions 1-10 (MT exam), and the second corresponding to sessions 11-18.

Last revision: May 2021.

Readings:

Ballard, D. H. (1999). *An introduction to natural computation*. MIT Press.

Churchland, P. S., & Sejnowski, T. J. (2016). *The computational brain*. MIT Press.

Conway, B.R. and Livingstone, M.S. (2007) Perspectives on Science and Art Curr Opin Neurobiol. 17(4): 476-482.

Domingos, P. (2015). *The master algorithm*. Basic Books.

Hertz, J., Krogh, A., & Palmer, R. (1991). *Introduction to the theory of neural computation*. CRC.

Howard-Jones P.A. (2014) Neuroscience and education: myths and messages. Nature Reviews Neuroscience 15:817-824

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

Levitin D.J and Tirovolas A.K. (2009) Current advances in the cognitive neuroscience of music. Ann N Y Acad Sci. 1156:211-31

Livingstone, M.S. (2018) What Art Can Tell Us About the Brain - YouTube

McCorduck, P. (2004). *Machines who think*. CRC.

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

Moore, D. S. And Shenk, D. (2017) The heritability fallacy. WIREs Cogn Sci 2017, 8:e1400. doi: 10.1002/wcs.1400

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

Pagán, O. R. (2014). *The first brain: the neuroscience of planarians*. Oxford University Press.

Ramachandran, V.S. (2003) Reith lecture. http://www.bbc.co.uk/radio4/reith2003/lecture3.shtml

RWS: Readings in Sapolsky, R. W. (2017) *Behave: The Biology of Humans at Our Best and Worst*

Sejnowski, T. J. (2018). *The deep learning revolution*. MIT Press.

Stanford Encyclopedia of Philosophy http://plato.stanford.edu/

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