

## Neurobiology HMS130 | HMS230

Harvard / GSAS 78454

### Visual object recognition: From computational and biophysical algorithms to cognition

FALL 2017

#### Overview

Visual recognition is essential for most everyday tasks including navigation, reading and socialization. Visual pattern recognition is also important for many engineering applications such as automatic analysis of clinical images, face recognition by computers, security tasks and automatic navigation. In spite of the enormous increase in computational power over the last decade, humans still outperform the most sophisticated engineering algorithms in visual recognition tasks. In this course, we will examine how circuits of neurons in visual cortex represent and transform visual information. The course will cover the following topics: functional architecture of visual cortex, lesion studies, physiological experiments in humans and animals, visual consciousness, computational models of visual object recognition, computer vision algorithms.

#### Class web site

[http://klab.tch.harvard.edu/academia/classes/hms\\_neuro300\\_vision/index.html](http://klab.tch.harvard.edu/academia/classes/hms_neuro300_vision/index.html)

(can be accessed through: <http://tinyurl.com/vision-class> )

Lecture notes, slides, reading assignments and other information will be posted in the class web site.

**Location:** Biolabs 1075

#### Course Meeting Times and Schedule

Mondays 3:30 pm to 5:30 pm

Lectures: 60 minutes / week.

Reading assignment discussion: 60 minutes/week

**Faculty:** Gabriel Kreiman

Invited guest lectures by: Camille Gomez-Laberge, Jiye Kim, Carlos Ponce, Leyla Isik, William Lotter, Frederico Azevedo, Andrei Barbu

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#### Prerequisites:

Life Sciences 1a (or Life and Physical Sciences A) and Life Sciences 1b. [or equivalent]

Recommended: Math (Maa/Mab, Math1A,1B, Math19a or equivalent). Physical Sciences 1. MCB80.

#### Topics:

- Introduction to pattern recognition. Why is vision difficult? Overview of key questions in the field.
- Characterization of the visual input. Natural image statistics.
- The retina, LGN and primary visual cortex. Neurophysiology and neuroanatomy.
- Lesion studies in humans and animals.
- Adventures into terra incognita: Neurophysiology beyond primary visual cortex.
- Electrical stimulation in visual cortex and causality.

- Biophysically-inspired computational models of visual object recognition.
- Computer vision. Engineering algorithms and their applications. Machine learning applications to vision.
- Human perception. Psychophysics .Visual Illusions.
- Engineering and prosthetic devices for visual recognition
- Towards understanding subjective visual perception and consciousness.

### **Suggested Books**

Ullman S (1996) High-level vision. MIT Press.

Wandell BA (1995) Foundations of vision. Sunderland Sinauer Associates.

Chalupa LM and Werner JS (editors) (2003). The Visual Neurosciences. MIT Press.

Ripley. Pattern recognition and neural networks (1996). Cambridge University Press.

Rao, Olshausen and Lewicki (eds) (2002). Probabilistic models of the brain. MIT Press.

Koch C (2005) The quest for consciousness. Roberts & Company Publishers.

Deco, G. and E.T. Rolls, Computational Neuroscience of Vision, Oxford Oxford University Press.

Dayan and Abbott (2002). Theoretical Neuroscience. MIT Press.

Horn BKP. Robot Vision. MIT Press.

Kriegeskorte N and Kreiman G. (2011) Understanding visual population codes. MIT Press.

Davies ER. (2005). Machine Vision, Third Edition: Theory, Algorithms, Practicalities (Signal Processing and its Applications). Elsevier.

### **Homework, Reading assignments and writing requirements**

Each week, students have to read, understand and discuss a scientific paper. The paper relates to the topics covered in the previous class and illustrates state-of-the-art research efforts in the field.

Students are required to hand in a discussion of the reading assignment including the following two points (typically half a page to one page):

- 1) A critic of the paper including missing controls or alternative interpretation of the findings or a critical discussion of the findings
- 2) Two follow up questions (computational modeling or experiments or computer vision applications)

Do not copy and paste from the paper (the instructor has already read the papers...).

Homework is due (electronic format) before the beginning of each class (for the paper discussed the previous week). For a detailed schedule of reading assignments and homework, click here.

Final paper. A final paper is due at the end of the class (details to be provided in class)

### **Grading**

Final grades are computed as follows:

Homework	– 60%
Class discussion	– 20%
Final paper	– 20%

## Schedule

CLASS	Date	Title	Comment
	09/04/17	<b>No class: Labor Day</b>	
1	09/11/16	Introduction to visual pattern recognition.	Introduction class.
2	09/18/17	Why is vision difficult? Natural image statistics and the retina	Discussion Reading 1.
3	09/25/17	Lesions and neurological examination of extrastriate visual cortex.	HW1 due. Discussion Reading 2.
4	10/02/17	Psychophysical studies of visual object recognition. [Kim]	HW2 due. Discussion Reading 3.
	<b>10/09/17</b>	<b>No class: Columbus Day</b>	<b>Note: HW3 due via email on 10/10/17.</b>
5	10/16/17	Primary visual cortex. [Gomez-Laberge]	Discussion Reading 4.
6	10/23/17	Adventures into terra incognita: probing the neurophysiological responses along the ventral visual stream. [Azevedo]	HW4 due. Discussion Reading 5.
7	10/30/17	First steps into inferior temporal cortex. [Ponce]	HW5 due. Discussion Reading 6.
8	11/06/17	From the highest echelons of visual processing to cognition. [Isik]	HW6 due. Discussion Reading 7.
9	11/13/17	From correlation to causation: electrical stimulation of visual cortex	HW7 due. Discussion Reading 8.
10	11/20/17	First steps towards in silico vision. Computational models of the ventral visual stream	HW8 due. Discussion Reading 9.
11	11/27/17	Computer Vision [Lotter]	HW9 due. Discussion Reading 10.
12	12/04/17	Vision and Language [Barbu]	HW10 due. Discussion Reading 11.
13	12/11/17	Extra optional class: Visual consciousness.	<b>Note: HW11 Due via email on 12/05/17.</b>
			Final paper due 12/14/17.