Psychology 599 - Special Topics

Bayesian Approaches to Visual Perception

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Fall 2003 (Scheduled class time may change)

Do you see the corners of this piece of paper as right angles – even though their projections on your retina are almost never right angles?

A powerful set of mathematics, theories, models, and predictions have been developed based on the premises that visual perception (or perception in general) is about inferring the most probable interpretation of the sensory inputs, given prior knowledge about the environment.

This class will provide a selected overview on how the language of Bayesian inference and ideal-observer analysis have been applied to topics in shape perception, object recognition, motion perception, color constancy, visual search, eye movement control, and cue integration. We will look at how considerations of the statistical properties of a natural scene predict and explain psychophysical data and constrain the theorizations on neural encoding and processing of visual inputs.

Students will gain both practical and theoretical understanding of the subject matter. Relevant computational techniques will be introduced in principle and as programming exercises. The course is suitable for graduate students of all levels in all disciplines of vision science (psychology, biology, engineering). Students with programming experience, a strong interesting in visual psychophysics or computational neural science, and general competency in linear algebra, probability theory, or statistics will benefit most from the class.

Text: Rao, Olshausen, & Lewicki. *Probabilitic Models of the Brain – Perception and Neural Function*. MIT Press. (Primary)
Reading materials: selected articles
Grades: participation – 10 %, class presentation - 25%, homework and programming assignments - 25%, term paper/project - 40%.

Class will meet once a week for 3.5 hours, include 1.5 hours of lab.

Week 1: Preambles, logistics, schedules, and my standard lecture on Bayesian approaches

Week 2: How to Bayes I
Introduction. Textbook
(*)Kersten D, Mamassian P, & Yuille A. (2003 *in press*) Object perception as Bayesian inference. *Annual Reviewof Psychology*.

Week 3: How to Bayes II
Ch. 1, textbook
(*)Mamassian P, Landy MS (1998) Observer biases in the 3D interpretation of line drawings. *Vision Research* 38: 2817–2832

Week 4: How to Bayes III
Ch. 2, textbook

Week 5: Explaining motion perception by “slow and smooth”
Ch. 4, textbook

Week 6: Cue combination
Ch. 3, textbook
(*)Maloney LT. (2002) Illuminant estimation as cue combination. *J Vis*. 2(6):493-504.

Week 7: Bayesian approaches to color and lightness perception
(*)Brainard DH, Freeman WT. (1997) Bayesian color constancy. *J Opt Soc Am A*. 14(7):1393-411.
(*)Purves D, Lotto RB, Williams SM, Nundy S, Yang Z. (2001) Why we see things the way we do: evidence for a wholly empirical strategy of vision. *Philos Trans R Soc Lond B Biol Sci*. 356(1407):285-97.
Lotto RB, Purves D. (1999) The effects of color on brightness. *Nat Neurosci.* 2(11):1010-4.

Week 8: Thinking about object recognition – a discussion
(*)Riesenhuber M, Poggio T. 1999. Hierarchical models of object recognition in cortex. *Nat Neurosci*. 2(11):1019-25.
(*)Tjan B.S. (2002). Object Recognition. *In* Arbib M. (Ed.), *The Handbook of Brain Theory and Neural Networks*, 2nd Ed. Cambridge, MA: MIT Press.
(*)Liu Z, Knill DC, & Kersten D. 1995. Object Classification for Human and Ideal Observers. *Vision Research* 35: 549-68.
Tjan B.S., Braje W.L., Legge G.E., & Kersten D. (1995). Human efficiency for recognizing 3-D objects in luminance noise. *Vision Research* 35 (21), 3053-69.
Liu Z, & Kersten D. 1998. 2D observers for human 3D object recognition? *Vision Research* 38: 2507-19.

Week 9: Information Theoretic Approaches to Neural Coding
Ch. 6, textbook

Week 10: Information theoretic approaches to eye movement controls
(*)Legge G.E., Klitz T.S., & Tjan B.S. (1997). Mr. Chips: An ideal observer model of reading. *Psychology Review* 104 (3), 524-553
(*)Legge G.E., Hooven T.A., Klitz T.S., Mansfield J.S., Tjan B.S. (2002). Mr. Chips 2002: new insights from an ideal-observer model of reading. *Vision Research* 42(18):2219-2234.

Week 11: When Bayesians play 20 Questions
Ch. 7, textbook

Week 12: Sparse code and natural statistics
(*)Olshausen BA, Field HJ (1997). Sparse coding with an overcomplete basis set: a strategy employed by V1? *Vis Res*, 37, 3311-3325.
Ch. 13, textbook

Week 13: Natural statistics and orientation tuning
Ch. 9, textbook
(*)Geisler WS, Perry JS, Super BJ, Gallogly DP. (2001) Edge co-occurrence in natural images predicts contour grouping performance. *Vision Res*. 41(6):711-24.

Week 14: Natural statistics and neural inhibitations
Ch. 10, textbook

Week 15: Bayesian, generative models, and cortical feedbacks
Ch. 16, textbook