

Introduction to Neural Networks

Psy 5038W, Fall 2009, 3 credits
Psychology Department , University of Minnesota

Place: S150 Elliott Hall
Time: 9:45-11:00 MW

Course home pages: courses.kersten.org

Instructor: Daniel Kersten, Office: S212 Elliott Hall, Phone: 625-2589, email: kersten@umn.edu
Office hours: Mondays 11:00 to 12:00 and by appointment.

TA: Michael Blank, Office: email: blan0138@umn.edu
Office hours: 11:00-12:00 on Tuesdays, in Elliott Hall S501, and by appointment.

Course description. Introduction to large scale parallel distributed processing models in neural and cognitive science. Topics include: linear models, statistical pattern theory, Hebbian rules, self-organization, non-linear models, information optimization, and representation of neural information. Applications to sensory processing, perception, learning, and memory.

General Readings and Software

- [Lecture notes](http://gandalf.psych.umn.edu/~kersten/kersten-lab/courses/Psy5038WF2007/5038Syllabus.html#LectureNotes) (<http://gandalf.psych.umn.edu/~kersten/kersten-lab/courses/Psy5038WF2007/5038Syllabus.html#LectureNotes>)
- Gopen, G. D., & Swan, J. A., 1990. The Science of Scientific Writing. *American Scientist*, 78, 550-558. ([pdf](#))
(For more information, see: [Mathematica Information Center](http://library.wolfram.com/infocenter/). (<http://library.wolfram.com/infocenter/>))
- [Mathematica for students](http://www.wolfram.com/products/student/mathforstudents/index.html) (<http://www.wolfram.com/products/student/mathforstudents/index.html>)
 - Learning center: <http://www.wolfram.com/learningcenter/>
 - [Instructions for accessing Mathematica](#)
- **Supplementary Reading**

*Anderson, James. (1995) *Introduction to Neural Networks*, MIT Press.

***Bishop, C. M. (1995). *Neural Networks for Pattern Recognition*. Oxford: Oxford University Press.

***Bishop, C. M. (2006). *Pattern recognition and machine learning*. New York: Springer.

*Dayan, P., & Abbott, L. F. (2001). *Theoretical neuroscience : computational and mathematical modeling of neural systems*. Cambridge, Mass.: MIT Press.

Freeman, J. A. (1994). *Simulating Neural Networks with Mathematica*. Reading, MA: Addison-Wesley Publishing Company.
<http://library.wolfram.com/infocenter/Books/3485/>

**Gershenfeld, N. A. (1999). *The nature of mathematical modeling*. Cambridge ; New York: Cambridge University Press.

**Hertz, J., Krogh, A., & Palmer, R. G. (1991). *Introduction to the theory of neural computation* (Santa Fe Institute Studies in the Sciences of Complexity ed.). Reading, MA: Addison-Wesley Publishing Company.

Koch, C., & Segev, I. (Eds.). (1998). *Methods in Neuronal Modeling : From Ions to Networks* (2nd ed.). Cambridge, MA: MIT Press.

***MacKay, D. J. C. (2003). *Information theory, inference, and learning algorithms*. Cambridge, UK ; New York: Cambridge University Press. <http://www.inference.phy.cam.ac.uk/mackay/itila/book.html>

Penrose, A. M., & Katz, S. B. (1998). *Writing in the Sciences: Exploring Conventions of Scientific Discourse*. New York: St. Martin's Press, Inc.

*Rolls, E. T., & Treves, A. (1998). *Neural networks and brain function*. Oxford ; New York: Oxford University Press.

**Neural/Cognitive Science*

***Physics/Applied Math*

****Statistical/machine learning*

Grade Requirements

There will be a mid-term, final examination, programming assignments, as well as a [final project](#). The grade weights are:

- Homework/programming: 28%
- Mid-term examination (covering first half of semester): 16%
- Final examination (covering 2nd half of semester): 16%
- Final project : 40% (four parts: 2%+5%+5%+28%)

The programming assignments will use the *Mathematica* programming environment. No prior experience with *Mathematica* is necessary. [List of Computer Labs at the University of Minnesota](#).

Assignment due **BEFORE** class start time (9:05 am) on the day due. You can use the downloaded Mathematica notebook for the assignment as your template, add your answers, and email your finished assignment to the TA. You can copy and paste any code bits you need from the Lecture notebooks. But of course, you cannot copy and paste code or any other answer materials from someone else.

Outline & Lecture Notes

*(NOTE: Updated links to lecture material below will be revised and posted on the day of the lecture
--if you want a preview, [check out lectures from 2007](#))*

All lecture notes are in Mathematica Notebook and pdf format. You can download the Mathematica notebook files below to view with Mathematica or [MathPlayer](#) (which is free).

		Date	Lecture	Additional Readings & supplementary material	Assignments due
I.	1	Sep 9	Introduction (pdf file) Mathematica notebook Instructions for accessing Mathematica	Mathematica screencast Neuroscience tutorial (Clinical, Wash. U.) Top 100 Brain Structures fMRI4Newbies	
	2	Sep 14	The neuron (pdf file) Mathematica notebook	Hodgkin-Huxley.nb Koch & Segev, 2000 (pdf) Meunier & Segev, 2002 (pdf)	
	3	Sep 16	Neural Models, McCulloch-Pitt (pdf file) Mathematica notebook	Koch, C., & Segev, I. (Eds.). (1998) (pdf)	
	4	Sep 21	Generic neuron model (pdf file) Mathematica notebook		
II.	5	Sep 23	Lateral inhibition (pdf file) Mathematica notebook	Hartline (1972) (pdf)	
	6	Sep 28	Matrices (pdf file) Mathematica notebook		PS 1. Introduction to Mathematica , vectors, cross-correlation
	7	Sep 30	Linear systems, learning & Memory (pdf file) Mathematica notebook		
	8	Oct 5	Linear Associator (pdf file) Mathematica notebook	einstein64x64.jpg shannon64x64.jpg	
			Sampling, Summed vector	ProbabilityOverviewNN.nb	

III.	9	Oct 7	memory (pdf file) Mathematica notebook		
	10	Oct 12	Non-linear networks, Perceptron (pdf file) Mathematica notebook	LeNet-5	PS 2. Lateral inhibition
	11	Oct 14	Regression, Widrow-Hoff (pdf file) Mathematica notebook		
	12	Oct 19	Multilayer feedforward nets, Backpropagation (pdf file) Mathematica notebook	Backpropagation.m Poirazi, Brannon & Mel (2003) (pdf) Williams (1992) (pdf)	
IV.	13	Oct 21	Science writing (pdf) (Mathematica notebook)	Gopen & Swan, 1990 (pdf) Hopfield (1982)(pdf)	
	14	Oct 26	<i>MID-TERM</i>	MID-TERM STUDY GUIDE	MID-TERM (16%)
	15	Oct 28	Networks and Visual Representation (pdf file) Mathematica notebook	Carrandini, Heeger, Movshon (1996)(pdf)	
	16	Nov 2	Neural Representation and coding (pdf file) Mathematica notebook	Sanger (2003) (pdf) Quiroga, R. Q., Reddy, L., Kreiman, G., Koch, C., & Fried, I. (2005).(pdf)	<i>PS 3. Learning</i> (pdf file)
	17	Nov 4	Self-organization, Principal Components Analysis (pdf file) Mathematica notebook	Supplement: ContingentAdaptation.nb	
	18	Nov 9	Discrete Hopfield network (pdf file) Mathematica notebook	Hopfield (1982) (pdf) Marr & Poggio (1976) (pdf)	
	19	Nov 11	Graded response Hopfield network (pdf file) Mathematica notebook	Hopfield (1984) (pdf) Durstewitz et al. (2000) (pdf)	PROJECT IDEAS For demonstration style projects, see the Wolfram Demonstration site . A specific example.
	20	Nov 16	Boltzmann machine (pdf file) Mathematica notebook	Sculpting the energy function, interpolation (pdf file) Mathematica notebook)	
	21	Nov 18	Adaptive maps (pdf file) Mathematica notebook	smallRetinaCortexMap.nb GravleftveDan.jpg	<i>PS 4 Hopfield network</i> Final project title & paragraph outline (2%)
	22	Nov 23	Probability (pdf file) Mathematica notebook	Griffiths and Yuille (2006) (pdf) Jordan, M. I. and Bishop. C. MIT Artificial Intelligence Lab Memo 1562, March 1996. Neural networks.	
	23	Nov 25	More on neural coding, Generative models, Bayes nets and inference (pdf file) Mathematica notebook	Knill & Pouget (2004) (pdf) Pouget et al. (2006) (pdf)	
	24	Nov 30	Belief Propagation (pdf) Mathematica notebook	Pattern Recognition and Machine Learning, Chapter 8. Christopher M. Bishop (pdf)	

			Weiss Y. (pdf)	
V.	25	Dec 2	EM (pdf) Mathematica notebook	
	26	Dec 7	Bayes decision theory (pdf) Mathematica notebook	Fisher's linear discriminant notes (pdf) Mathematica notebook
	27	Dec 9	Kalman filter, fisher discriminant (pdf) Mathematica notebook	Kalman notes (pdf) Rao & Ballard 1999 (pdf) Wolpert et al (1995) (pdf)
	28	Dec 14	Bias/Variance, Wrap-up & Review (pdf) Mathematica notebook	Bias/Variance notes (pdf)
		Dec 16	EXAM (official last instruction day)	FINAL STUDY GUIDE
		Dec 23	(last day of fall semester)	Submit Final Revised (extended deadline!) Draft of Project (28%)

Final Project Assignment.

This course teaches you how to understand cognitive and perceptual aspects of brain processing in terms of computation. Writing a computer program encourages you to think clearly about the assumptions underlying a given theory. Getting a program to work, however, tests just one level of clear thinking. By writing *about* your work, you will learn to think through the broader implications of your final project, and to effectively communicate the rationale and results in words.

Your final project will involve: 1) a computer simulation and; 2) a 2000-3000 word final paper describing your simulation. For your computer project, you will do one of the following: 1) Devise a novel application for a neural network model studied in the course; 2) Write a program to simulate a model from the neural network literature ; 3) Design and program a method for solving some problem in perception, cognition or motor control. The results of your final project should be written up in the form of a short scientific paper, describing the motivation, methods, results, and interpretation. Your paper will be critiqued and returned for you to revise and resubmit in final form. You should write for an audience consisting of your class peers. You may elect to have your final paper published in the course's web-based electronic journal.

Completing the final paper involves 3 steps:

- Outline.** You will submit a working title and paragraph outline by the deadline noted in the syllabus. These outlines will be critiqued in order to help you find an appropriate focus for your papers. (**2%** of grade). (Consult with the instructor or TA for ideas well ahead of time).
- Complete draft.** You will then submit a complete draft of your paper (**2000-3000 words**). Papers must include the following sections: Abstract, Introduction, Methods, Results, Discussion, and Bibliography. Use citations to motivate your problem and to justify your claims. Figures should be numbered and have figure captions. Cite authors by name and date, e.g. (Marr & Poggio, 1979). Use a standard citation format, such as APA. Papers must be typed, with a page number on each page. Each paper will be reviewed with specific recommendations for improvement. (**5%** of grade)
- Peer commentary.** Each student will submit a paragraph on an anonymous paired project draft (**5%** of grade)

4. **Final draft.** You will submit a final revision for grading. (28% of grade). The final draft must be turned in by the date noted on the syllabus. Students who wish to submit their final papers to be published in the class electronic journal should turn in both paper and electronic copies of their reports.

If you choose to write your program in Mathematica, your paper and program can be combined can be formatted as a Mathematica notebook. See: [Books and Tutorials on Notebooks](#).

Your paper will be critiqued and returned for you to revise and resubmit in final form. You should write for an audience consisting of your class peers.

Some Resources:

Student Writing Support: Center for Writing, 306b Lind Hall and satellite locations (612.625.1893)
<http://writing.umn.edu>.

Online Writing Center: <http://www.owc.umn.edu>

NOTE: Plagiarism, a form of scholastic dishonesty and a disciplinary offense, is described by the Regents as follows: Scholastic dishonesty means plagiarizing; cheating on assignments or examinations; engaging in unauthorized collaboration on academic work; taking, acquiring, or using test materials without faculty permission; submitting false or incomplete records of academic achievement; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement; or altering, forging, or misusing a University academic record; or fabricating or falsifying of data, research procedures, or data analysis. <http://www1.umn.edu/regents/policies/academic/StudentConductCode.html>

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