PSY5038F2018

PSY 5038W - Introduction to Neural Networks

Fall 2018

Class #: 34494
9:45AM-11:00AM MW
Elliott Hall N391

(Course web pages: courses.kersten.org)

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

Teaching assistant: Yijun Ge, gexxx119@umn.edu, N10 Elliott Hall
Office hours: Wednesdays 11:00 to 12:00 and by appointment.
(Note: N10 is in a secured area. Please send email to TA to open door.)

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.

Prerequisites: Linear algebra, multivariate calculus.

Readings¶

Lecture notes (see below)

Software¶

Mathematica¶

Mathematica is the primary programming environment for this course. Students who have registered for the course will have Google Docs access through the Psychology Department's site license.

Alternatives: *Mathematica is available in several labs on campus, go to http://www.oit.umn.edu/computer-labs/software/index.htm*
You may wish to purchase *Mathematica for Students* see http://www.wolfram.com/products/student/mathforstudents/index.html.
You can also access ***Mathematica*** on the CLA servers:

mac (Note: you may have to change the forward slash to a back slash)
windows

If you never programmed before go here. If you have programming experience, go here.

For user help on using Mathematica, see: http://mathematica.stackexchange.com

Learning center: http://www.wolfram.com/learningcenter/

Python/Jupyter/IPython¶

http://ipython.org
http://jupyter-notebook-beginner-guide.readthedocs.org/en/latest/index.html
http://www.scipy.org

For an online course in using Python and PsychoPy for research in human vision see:
http://nbviewer.ipython.org/github/gestaltrevision/python_for_visres/blob/master/index.ipynb

Supplementary¶

http://www.pybrain.org
https://code.google.com/p/neurolab/
http://briansimulator.org

Writing¶

- Gopen, G. D., & Swan, J. A., 1990. The Science of Scientific Writing. American Scientist, 78, 550-558. (pdf)
- ***Supplementary:***
  - The Sense of Style: The Thinking Person's Guide to Writing in the 21st Century (2014), Pinker, Steven. (amazon link)

- *Penrose, A. M., & Katz, S. B. (1998). Writing in the Sciences: Exploring Conventions of Scientific Discourse. New York: St. Martin's Press, Inc.*
- *American Psychological Association. (2009). Publication manual of the American Psychological Association (6th ed.). Washington, DC: American Psychological Association*

- ***Writing assistance.*** *THE CENTER FOR WRITING offers free one-to-one writing assistance to undergraduate and graduate students, with appointments up to 45 minutes. Nonnative speaker specialists are available. For more information, see http://writing.umn.edu.*
- Psychology department resources: http://writing.psych.umn.edu/student-resources

Supplementary readings¶

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

_Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep Learning*. MIT Press. (online)
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*
***_Murphy, K. P. (2012). Machine Learning: a Probabilistic Perspective. MIT Press.

**Neural/Cognitive Science*
***Physics/Applied Math*
****Statistical/machine learning*

Grade Requirements¶

There will be programming assignments, as well as a final project. The grade weights are:

- Exercise/programming assignments: 55%
- Final project presentations: 5 %
- 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.[

](http://www2.publabs.umn.edu/publab/text/locations.html)Your completed problem set assignment should be uploaded to Canvas by midnight

on the date due. In general you should use the downloaded Mathematica notebook as your template, then add your answers, and then upload the finished assignment. 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.

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Outline & Lecture Notes¶

(Under construction)¶

http://onestop.umn.edu/calendars/

_(NOTE: Links to revised lecture material below will be posted on the day of the lecture.
Links to the pdfs

Lecture notes are in Mathematica Notebook and pdf format. You can download the Mathematica notebook files below to view with Mathematica or Wolfram CDF Player (which is free).

Lecture	Date	Lecture	A
1	Sep 5	Introduction [Mathematica notebook](/courses/71054/files/3310692/download?wrap=1 "Lect_1_Introduction.nb") ([pdf](/courses/71054/files/3310707/download?wrap=1 "Lect_1_Introduction.nb.pdf"))	[(
2	Sep 10	The neuron [(pdf file](/courses/71054/files/3378180/download?wrap=1 "Lect_2_TheNeuron.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3378177/download?wrap=1 "Lect_2_TheNeuron-1.nb")	[D [(c
3	Sep 12	Neural Models, McCulloch-Pitt ([pdf file](/courses/71054/files/3415176/download?wrap=1 "Lect_3_NeuralModeling.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3415175/download?wrap=1 "Lect_3_NeuralModeling.nb")	In "
4	Sep 17	Generic neuron model ([pdf file](/courses/71054/files/3477521/download?wrap=1 "Lect_4_GenericModel.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3477511/download?wrap=1 "Lect_4_GenericModel.nb")	
5	Sep 19	Lateral inhibition [(](Lectures/Lect_5_LatInhibition/Lect_5_LatInhibition.nb.pdf)[pdf file](/courses/71054/files/3519528/download?wrap=1 "Lect_5_LatInhibition.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3519521/download?wrap=1 "Lect_5_LatInhibition.nb")	H
6	Sep 24	Matrices ([pdf file](/courses/71054/files/3582868/download?wrap=1 "Lect_6_Matrices.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3582875/download?wrap=1 "Lect_6_Matrices.nb")	
7	Sep 26	Linear systems, learning & memory ([pdf file](/courses/71054/files/3620907/download?wrap=1 "Lect_7_LinearSystems.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3620901/download?wrap=1 "Lect_7_LinearSystems.nb")	
8	Oct 1	Linear recall, association and memory simulations ([pdf file](/courses/71054/files/3693072/download?wrap=1 "Lect_8_HeterAuto.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3693069/download?wrap=1 "Lect_8_HeterAuto.nb")	

9	Oct 3	Overview of non-linear networks, discriminative models, Perceptron, SVMs ([pdf file](/courses/71054/files/3740368/download?wrap=1 "Lect_9_Perceptron.nb.pdf"))| , [Mathematica notebook](/courses/71054/files/3740361/download?wrap=1 "Lect_9_Perceptron.nb")	S (/ fi T
10	Oct 8	Supervised learning as regression, Widrow-Hoff, backprop & deep learning, ([pdf file](/courses/71054/files/3815215/download?wrap=1 "Lect_10_RegressWid.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3815213/download?wrap=1 "Lect_10_RegressWid.nb")	[n e " 3
11	Oct 10	Hopfield networks [(pdf file](/courses/71054/files/3857749/download?wrap=1 "Lect_11_Hopfield.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3857745/download?wrap=1 "Lect_11_Hopfield.nb")	H c 3 w c S " k
12	Oct 15	Boltzmann machine ([pdf file](/courses/71054/files/3932721/download?wrap=1 "Lect_12_Boltzmann.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3932718/download?wrap=1 "Lect_12_Boltzmann.nb")	E ir "

13	Oct 17	Probability and neural networks ([pdf file](/courses/71054/files/3971494/download?wrap=1 "Lect_13_Probability.nb.pdf"))| [Mathematica notebook](/courses/71054/files/3971493/download?wrap=1 "Lect_13_Probability.nb")	G " C " N 7
14	Oct 22	Multivariate distributions, Regression, Interpolation, perceptual completion ([pdf](/courses/71054/files/4032724/download?wrap=1 "Lect14_MultinormalsRegressionSculptingCost.nb.pdf")) [Mathematica notebook](/courses/71054/files/4032721/download?wrap=1 "Lect14_MultinormalsRegressionSculptingCost.nb")	N w
15	Oct 24	Graphical models ([pdf](/courses/71054/files/4073219/download?wrap=1 "Lect_15_ProbabilityGraphicalModels-1.nb.pdf")) [Mathematica notebook](/courses/71054/files/4073214/download?wrap=1 "Lect_15_ProbabilityGraphicalModels-1.nb")	F w w d C

16	Oct 29	Belief Propagation: regression and interpolation revisited [(pdf](/courses/71054/files/4136590/download?wrap=1 "Lect_16_BeliefProp.nb.pdf")) [Mathematica notebook](/courses/71054/files/4136599/download?wrap=1 "Lect_16_BeliefProp.nb")
17	Oct 31	Supervised learning: neural networks in the context of machine learning ([pdf](/courses/71054/files/4180102/download?wrap=1 "Lect17_SupervisedNNsAndML.nb.pdf")) [Mathematica notebook](/courses/71054/files/4180101/download?wrap=1 "Lect17_SupervisedNNsAndML.nb")
18	Nov 5	Deep learning, DCNNs Feedforward architectures for recognition Keynote presentation ([pdf](/courses/71054/files/4248803/download?wrap=1 "CNNsLect18.pdf"))
19	Nov 7	DCNNs Keynote presentation ([pdf](/courses/71054/files/4288503/download?wrap=1 "Lect19DCNNs-1.pdf")) [Mathematica notebook with demos](/courses/71054/files/4360760/download?wrap=1 "Lect19DeepLearningDCNNS-1.nb") (revised 11/12/18)

20	Nov 12	Recurrent neural networks (RNNs), sequence modeling [Keynote presentation](/courses/71054/files/4364075/download?wrap=1 "RNNs-1.key") [(pdf](/courses/71054/files/4364079/download?wrap=1 "RNNs.pdf")[)](/courses/71054/files/4360747/download?wrap=1 "RNNs.key") [Mathematica notebook with demos](/courses/71054/files/4360750/download?wrap=1 "RNNMathematicalIntro.nb")	K "K

21	Nov 14	Markov chain Monte Carlo (MCMC) sampling [Mathematica notebook](/courses/71054/files/4485616/download?wrap=1 "Lect_21_MoreSamplingMCMC-1.nb") ([pdf](/courses/71054/files/4485620/download?wrap=1 "Lect_21_MoreSamplingMCMC-1.nb.pdf"))	L p 1 k c c c
22	Nov 19	MCMC continued (see Lecture 21 notebook)	F n n N I s l [p
23	Nov 21	Overview of python and jupyter notebooks for scientific computation/neural networks, and Bayesian computations. Starting python in the middle: [Jupyter notebook on colab](https://drive.google.com/open?id=1xQ7LN-6q7SptF0TdZ_kM2DlN25tE89r0) [Source jupyter notebook](/courses/71054/files/4527474/download?wrap=1 "Lect_21Intro_Python3.ipynb"). MCMC sampling using Python3 and PyMC3 [Jupyter notebook on colab](https://colab.research.google.com/drive/1N0CgswSGEpG4XKBy5g2zKO_Ps_gfR9yR) [Source jupyter notebook.](/courses/71054/files/4527479/download?wrap=1 "Lect_PyMC3.ipynb")	L n L [P L u C P g P E n L

24	Nov 26	Introduction to neural networks for self-organization Overview of visual system architecture Keynote ([pdf](/courses/71054/files/4602935/download?wrap=1 "Lect_24_VisualArchitectureLateral-2.pdf")) AdaptMaps [Mathematica notebook](/courses/71054/files/4602939/download?wrap=1 "SelfOrganizationAdaptMaps-1.nb") ([pdf](/courses/71054/files/4602949/download?wrap=1 "SelfOrganizationAdaptMaps-1.nb.pdf"))	S (
25	Nov 28	Introduction to neural networks for self-organization continued (see pdfs from previous lecture)	C S s c S M

[26](/courses/71054/files/4685569/download?wrap=1 "Lect_SelfOrgPCA_SVD_Oja.nb")	[Dec 3](/courses/71054/files/4685569/download?wrap=1 "Lect_SelfOrgPCA_SVD_Oja.nb")	Efficient coding. PCA, SVD, sparse coding [Mathematica notebook](/courses/71054/files/4685576/download?wrap=1 "Lect_SelfOrgPCA_SVD_Oja-1.nb") ([pdf](/courses/71054/files/4685619/download?wrap=1 "Lect_SelfOrgPCA_SVD_Oja.nb.pdf")) Scientific writing and presentations [Mathematica notebook](/courses/71054/files/4685626/download?wrap=1 "ScienceWriting.nb") [(pdf](/courses/71054/files/4685628/download?wrap=1 "ScienceWriting.nb.pdf"))	C a V

27	Dec 5	Clustering, EM, segmentation [Mathematica notebook](/courses/71054/files/4750417/download?wrap=1 "Lect_27_ClusteringEM-1.nb") ([pdf](/courses/71054/files/4750425/download?wrap=1 "Lect_27_ClusteringEM-1.nb.pdf")) (updated to work with Mathematica 11.3)	E % k Q k tl L

Dec 10			C
Dec 12	Last day of classes		C
Dec 20		End of Semester	

* * * ### 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:

1. **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).
2. **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)
3. **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.

If you choose to write your program in Mathematica, your paper and program can be combined can be formated 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://writing.umn.edu/sws/visit/online/index.html

NOTE: Plagiarism, a form of scholastic dishonesty and a disciplinaryoffense, is described by the Regents as follows: Scholasticdishonesty means plagiarizing; cheating on assignments or examinations;engaging in unauthorized collaboration on academic work; taking,acquiring, or using test materials without faculty permission; submittingfalse or incomplete records of academic achievement; acting alone or incooperation with another to falsify records or to obtain dishonestlygrades, honors, awards, or professional endorsement; or altering,forging, or misusing a University academic record; or fabricating orfalsifying of data, research procedures, or data analysis.http://regents.umn.edu/sites/regents.umn.edu/files/policies/Student_Conduct_Code.pdf

NOTE: Sexual Assault and higher education: Training modules and information
The Department of Psychology supports the efforts of the University of Minnesota towards prevention of sexual assault. We encourage all students to participate in the free online training that has been established for undergraduate students and graduate students. The training highlights pertinent issues regarding sexual assault, including, but not limited to: defining healthy relationships, consent, bystander intervention, and gender roles. Haven (for undergraduate students under the age of 25) and Haven Plus (for undergraduates over 25, graduate students, and professional students) is the training available at no cost to University of Minnesota students. Additionally, to learn more about how you can help reduce sexual assault at the University of Minnesota, please visit the Aurora Center.