5036WSyllabusF2019

Computational Vision

courses.kersten.org

Psychology Department , University of Minnesota
Psy 5036W, Fall 2019, 3 credits #34359

08:45 A.M. - 10:00 A.M. Mondays and Wednesdays
Elliott Hall N227

Instructor: Daniel Kersten. *Office*: S212 Elliott Hall. *Phone*: 612 625-2589 *email*: kersten@umn.edu
Office hours: Mondays 10:00-11:00 am or by appointment.

The visual perception of what is in the world is accomplished continually, instantaneously, and usually without conscious thought. The very effortlessness of perception disguises the underlying richness of the problem. We can gain insight into the processes and functions of human vision by studying the relationship between neural mechanisms and visual behavior through computer analysis and simulation. Students will learn about the anatomy and neurophysiology of vision and how they relate to the phenomona of perception. An underlying theme will be to treat vision as a process of statistical inference. There will be in-class programming exercises using the language Mathematica. No prior programming experience is required; however, some familiarity with probability, vector calculus and linear algebra is helpful.

Readings¶

Main¶

- Lecture notes, Main Readings & Supplementary Material are all available online.

Additional readings¶

Math and vision¶

- (**EV**) Early Vision. Yuille and Kersten. In *From Neuron to Cognition via Computational Neuroscience*, M.A. Arbib, James J. Bonaiuto Editors, Cambridge MA: The MIT Press, in 2016 (preprint pdf)
- Understanding Vision: Theory, Models, and Data. Li Zhaoping. 2014.(publisher page) (author's web outline)

Functional human vision¶

- (**FV**) *Foundations of Vision*. Wandell (web)

Neurophysiology¶

- (**NVN**) *The New Visual Neurosciences*. John S. Werner and Leo M. Chalupa, edts. 2014.

Software¶

Mathematica¶

Mathematica is the primary programming environment for this course. Students who have registered for the course will have 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.

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

Python/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

Writing¶

- Gopen, G. D., & Swan, J. A., 1990. The Science of Scientific Writing. American Scientist, 78, 550-558.

- **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

**Grade Requirements

**There will be programming assignments and a final project.

The grade weights are:

- Exercise/programming assignments: 55%

- Final project in-class presentations: 5 %

- Final project : 40% (five parts: 2% (title and outline) +5%(first draft) +5% (peer commentary) +8% (cover letter response) + 20% (final draft))

The programming assignments will use the *Mathematica* programming environment. No prior experience with *Mathematica* is necessary.

Assignment due By the 6 am on the day after the nominal due date. _**Late Policy: Assignments turned in within 24 hours following the due date will have 15% deducted from the assignment score. Assignments turned in between 24 and 48 hours following the due date will have 30% deducted from the score. Assignments more than 48 hours late will receive a score of zero.**_

Lectures¶

Check this section before each class for recent additions and revisions.

(5036W Course material from 2017)

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).

[University Calendar](http://onestop.umn.edu/onestop/calendar.html)	**Date**	**Lecture**	_**Main Readings**_	**Supplementary Material**	**Assign
I. Introduction	Sep 4	1\. Introduction to Computational Vision	_1.IntroToComputationalVision.nb _ Olshausen, B. A. (2013). Perception as an Inference Problem. In M. Gazzaniga (Ed.), The New Cognitive Neurosciences, 5th Edition (pp. 1â€"22). MIT Press. (pp. 1â€"18). MIT Press.	Screencast: http://www.wolfram.com/broadcast/screencasts/handsonstart/ (WITH AUDIO)[ ](Lectures/1_MultidisciplinaryStudy/FoxApertures2.mov)Check out demos under: **Life Sciences/Cognitive Science/Perception** and **Engineering & Technology/Image Processing** on the Mathematica Demonstrations site: http://demonstrations.wolfram.com/ _Kersten, D., & Yuille, A. (2003). Bayesian models of object perception. Current Opinion in Neurobiology, 13(2), 1-9. _ EV: Section 1	

	Sep 9	2.Limits to Vision	_2.LimitsToVision.nb__ Hecht, S., Shlaer, S., & Pirenne, M. H. (1942). Energy, quanta, and vision. Journal of General Physiology, 25, 819-840. _	Barlow, H. B. (1981). Critical Limiting Factors in the Design of the Eye and Visual Cortex. Proc. Roy. Soc. Lond. B, 212, 1-34. Baylor, D. A., Lamb, T. D., & Yau, K. W. (1979). Responses of retinal rods to single photons. Journal of Physiology, Lond., 288, 613-634. Tinsley, J. N., Molodtsov, M. I., Prevedel, R., Wartmann, D., Pons, J. E. E., Lauwers, M., & Vaziri, A. (2016). Direct detection of a single photon by humans. Nature Communications, 7, 1–9.	
	Sep 11	3\. The Ideal Observer	_3.TheIdealObserver.nb _	ProbabilityOverview.nb Griffiths, T. L., & Yuille, A. (2008). A primer on probabilistic inference. In M. Oaksford and N. Chater (Eds.). The probabilistic mind: Prospects for rational models of cognition. Oxford: Oxford University Press [(pdf](../../coursepapers/GriffithsYuilleProbPrimerTICsmmc1.pdf)). Try your luck against an ideal discriminator of dot density YesNoDotDiscriminationDemo.nb	Upload A courses/ Assignm
	Sep 16	4\. Ideal observer analysis: Humans vs. ideals. Neurons vs. ideals	_4.IdealObserverAnalysis.nb_	Kersten and Mamassian (2008), Ideal observer theory. The New Encyclopedia of Neuroscience, Squire et al., editors (pdf). Geisler, W. S. (2011). Contributions of ideal observer theory to vision research. Vision Research, 51(7), 771–781. Burgess, A. E., Wagner, R. F., Jennings, R. J., & Barlow, H. B. (1981)_. Efficiency of human visual signal discrimination. Science, 214(4516), 93-94\._ Deneve, S., Latham, P. E., & Pouget, A. (1999). Reading population codes: a neural implementation of ideal observers. Nature Neuroscience, 2(8), 740–745. Measure your absolute efficiency to discriminate dot density using a 2AFC task 2AFCDotDiscriminationDemo.nb	
II. Image formation, pattern synthesis	Sep 18	5.Psychophysics: tools & techniques	_5.Psychophysics.nb[](Lectures/5_PsychophysicsSKEobserver/5_Psychophysics.nb) _	SKEDetection2AFCInLineDisplay.nb Farell, B. & Pelli, D. G. (1999) Psychophysical methods, or how to measure a threshold and why. In R. H. S. Carpenter & J. G. Robson (Eds.), Vision Research: A Practical Guide to Laboratory Methods, New York: Oxford University (Press.http://psych.nyu.edu/pelli/ Morgenstern, Y., & Elder, J. H. (2012). Local Visual Energy Mechanisms Revealed by Detection of Global Patterns. Journal of Neuroscience, 32(11), 3679–3696\. For a free Matlab psychophysics package, see: [http://psychotoolbox.org](http://psychtoolbox.org/) For a free Python psychophysics package, see: http://www.psychopy.org	
	Sep 23	6\. Bayesian decision theory & perception	_6.BayesDecisionTheory.nb _ _Geisler, W. S., & Kersten, D. (2002). Illusions, perception and Bayes. Nat Neurosci, 5(6), 508-510\. ([pdf](http://gandalf.psych.umn.edu/%7Ekersten/kersten-lab/papers/GeislerKerstennn0602-508.pdf))_	[EV Section 3](../../coursepapers/YuilleKerstenFinalChapter2016.pdf#3)	
	Sep 25	7\. Limits to spatial resolution, image modeling, introduction to linear systems	_7.ImageModelLinearSystems.nb _ _Campbell, F. W., & Green, D. (1965). Optical and retinal factors affecting visual resolution. Journal of Physiology (Lond.), 181, 576-593\. ([pdf](../../coursepapers/CampbellGreen_JP1965.pdf))_	Williams, D. R. (1986). Seeing through the photoreceptor mosaic. 9(5), 193-197. LinearAlgebraReview.nb Convolutions_Tutorial.nb IPython convolutions notebook	Uploa (https://a course/v Problem
III. Early visual coding	Sep 30	8\. Linear systems analysis	_8.LinearSystemsOptics.nb _	EV: Section 2 _CSF.gif_ Tutorials: Fourier_neural_image.nb	

	Oct 2	9\. Features and filters. Spatial filter models of early human vision	_9.NeuralSpatialFiltering.nb _	Campbell, F. W., & Robson, J. R. (1968). Application of Fourier Analysis to the Visibility of Gratings. Journal of Physiology 197, 551-566. De Valois, R. L., Albrecht, D. G., & Thorell, L. G. (1982). Spatial frequency selectivity of cells in macaque visual cortex. Vision Res, 22(5), 545-559. Watson, A. B. (1987). Efficiency of a model human image code. J Opt Soc Am A, 4(12), 2401-2417. IPython demo of gabor filtering Steerable pyramids: http://www.cns.nyu.edu/~eero/steerpyr/	
	Oct 7	10\. Features and filters. Local processing & image analysis	_10.ImageProcessing.nb _ Gollisch, T., & Meister, M. (2010). Eye Smarter than Scientists Believed: Neural Computations in Circuits of the Retina. Neuron, 65(2), 150–164.	Albrecht, D. G., De Valois, R. L., & Thorell, L. G. (1980). Visual cortical neurons: are bars or gratings the optimal stimuli? Science, 207(4426), 88-90. Adelson, E. H., & Bergen, J. R. (1991). The plenoptic function and the elements of early vision. In M. S. Landy & J. A. Movshon (Eds.), Computational Models of Visual Processing. Cambridge, MA: The MIT Press: A Bradford Book. ClassificationImage demo ([ReverseCorrelation.nb](Reverse%20correlation/ReverseCorrelation.nb)) Ahumada, A. J., Jr. (2002). Classification image weights and internal noise level estimation. J Vis, 2(1), 121-131\. ([pdf](Reverse%20correlation/Ahumada-2002-jov-2-1-8.pdf)	Upload A (https://a course/v Problem %20Exer Assignm Assignm
	Oct 9	11\. Coding efficiency: Retina	_11.CodingEfficiency.nb _ Geisler, W. S. (2008). Visual perception and the statistical properties of natural scenes. Annu Rev Psychol, 59, 167-192\.	Laughlin, S. (1981). A simple coding procedure enhances a neuron's information capacity. Z Naturforsch [C], 36(9-10), 910-912. Atick, J. J., & Redlich, A. N. (1992). What does the retina know about natural scenes? Neural Computation, 4(2), 196–210\. Meister, M., & Berry, M. J., 2nd. (1999). The neural code of the retina. Neuron, 22(3), 435-450.[(pdf](../../coursepapers/meister+berry_99.pdf)) Srinivasan, M. V., Laughlin, S. B., & Dubs, A. (1982). Predictive coding: a fresh view of inhibition in the retina. Proc R Soc Lond B Biol Sci, 216(1205), 427-459. IPython demo of natural image statistics	
	Oct 14	12\. Coding efficiency: Cortex	_12.SpatialCodingEfficiency.nb _ _Simoncelli, E. P., & Olshausen, B. A. (2001). Natural image statistics and neural representation. Annu Rev Neurosci, 24, 1193-1216._	ContrastNormalizationNotes.nb Laughlin, S. B., de Ruyter van Steveninck, R. R., & Anderson, J. C. (1998). The metabolic cost of neural information. Nat Neurosci, 1(1), 36-41. Lennie, P. (2003). The cost of cortical computation. Curr Biol, 13(6), 493-497.[](../../coursepapers/LennieCurBio2003.pdf) Multi-resolution, image pyramids, and efficient coding: JepsonFleet2005pyramids_notes.pdf AdelsonPyramidRCA84.pdf	
IV. Intermediate-level vision, integration, grouping	Oct 16	13\. Edge detection	13.EdgeDetection.nb	Hubel, D. H., & Wiesel, T. N. (1977). Ferrier lecture. Functional architecture of macaque monkey visual cortex. Proc R Soc Lond B Biol Sci, 198(1130), 1-59. IPython demo of statistical edge detection	

Oct 21	14\. Objects and scenes from images. The visual cortical pathways and hierarchy.	_14.ScenesfromImages.nb __ von der Heydt R (2003) Image parsing mechanisms of the visual cortex. In: The Visual Neurosciences (Werner JS, Chalupa LM, eds.), pp 1139-1150\. Cambridge, Mass.: MIT press._ Kersten, D. J., & Yuille, A. L. (2014). Inferential Models of the Visual Cortical Hierarchy. In M. S. Gazzaniga & G. R. Mangun (Eds.), The New Cognitive Neurosciences, 5th Edition (pp. 1â€"22). MIT Press.[](http://vision.psych.umn.edu/users/kersten//kersten-lab/coursepapers/KerstenYuilleNewCogNeuro2014.pdf)	Zhou H, Friedman HS, von der Heydt R (2000) Coding of border ownership in monkey visual cortex. J Neuroscience 20: 6594-6611.
Oct 23	15\. Scene-based generative models	_15.SurfaceGeometryDepth.nb _ _Kersten, D., Mamassian, P., & Yuille, A. (2004). Object perception as Bayesian Inference. Annual Review of Psychology, 55, 271-304. _	
Oct 28	16\. Shape-from-X	_16.ShapeFromX.nb _	Reflectance map: Shape from shading: Horn BKP (1986) Robot Vision. Cambridge MA: MIT Press. Ch 11 Barron, J. T., & Malik, J. (2015). Shape, Illumination, and Reflectance from Shading. IEEE Transactions on Pattern Analysis and Machine Intelligence, 37(8), 1670â€"1687\. http://doi.org/10.1109/TPAMI.2014.2377712 Belhumeur, P. N., Kriegman, D. J., & Yuille, A. (1997). The Bas-Relief Ambiguity. ([pdf](https://pdfs.semanticscholar.org/71ac/0dc7634e4a56fd41dfac270ec5883fcbb44f.pdf)) Johnson, M. K., & Adelson, E. H. (2011). Shape Estimation in Natural Illumination. Computer Vision and Pattern Recognition (CVPR), 2553–2560. Muryy, A. A., Welchman, A. E., Blake, A., & Fleming, R. W. (2013). Specular reflections and the estimation of shape from binocular disparity. Proceedings of the National Academy of Sciences of the United States of America, 110(6), 2413–2418. cube.mov random.mov

Oct 30	17\. Shape from shading Overview of python/ipython for computational vision[ ](https://wakari.io/sharing/bundle/kersten/Lect_19Intro_Python)	_17\. Shape from shading.nb_ Lect_17Intro_Python.ipynb (source) _17\. IPython notebook_ Demos by Weichao Qiu and Dan Kersten, supplement to _**Early Vision**._ Yuille and Kersten. A chapter in _From Neuron to Cognition via Computational Neuroscience_, M.A. Arbib, James J. Bonaiuto Editors, Cambridge MA: The MIT Press, in 2016	[Anaconda](https://store.continuum.io/cshop/anaconda/) python installation recommended. We will use [Juypter/IPython](http://ipython.org), a browser-based notebook interface for python. See [here](http://nbviewer.ipython.org/github/ipython/ipython/blob/1.x/examples/notebooks/Part%205%20-%20Rich%20Display%20System.ipynb) for illustrations of IPython cell types, and [here](https://github.com/ipython/ipython/wiki/A-gallery-of-interesting-IPython-Notebooks) for a collection of sample notebooks. Look [here](http://iacs-courses.seas.harvard.edu/courses/am207/blog/installing-python.html) for some good tips on installation, as well as the parent directory for excellent ipython-based course material on scientific computing using Monte Carlo methods. For a quick start to scientific programming, see: http://nbviewer.ipython.org/gist/rpmuller/5920182 For a comphrensive coverage of scientific python see[:https://scipy-lectures.github.io](https://scipy-lectures.github.io) And for a ground-up set of tutorials on python see: http://learnpythonthehardway.org/book/ Switching from matlab to python? [http://wiki.scipy.org/NumPy_for_Matlab_User](http://mathesaurus.sourceforge.net/matlab-numpy.html) ProjectIdeasF2015.nb
Nov 4	18\. Motion: optic flow	_18.MotionOpticFlow.nb _ _OpenCV python demo:_ [OpticFlowSparse.ipynb](http://nbviewer.ipython.org/url/gandalf.psych.umn.edu/users/kersten/kersten-lab/courses/Psy5036W2015/Lectures/18.MotionOpticFlow/OpticFlowSparse.ipynb) needs: [648aa10.avi](Lectures/17_PythonForVision/648aa10.avi)	Horn, B. K. P., & Schunck, B. G. (1981). Determining Optical Flow. Artificial Intelligence, 17, 185-203. Optic Flow (2013) Florian Raudies, Scholarpedia, 8(7):30724\. doi: 10.4249/scholarpedia.30724 (with available matlab code) Optic flow matlab code from Michael Black's lab. Borst, A. (2007). Correlation versus gradient type motion detectors: the pros and cons. Philos Trans R Soc Lond B Biol Sci, 362(1479), 369-374. http://web.mit.edu/persci/people/adelson/illusions_demos.html [IPython aperture demo](http://nbviewer.ipython.org/url/gandalf.psych.umn.edu/users/kersten/kersten-lab/courses/Psy5036W2015/Lectures/17_PythonForVision/Aperture%20demo.ipynb) EV: Section 2.4 FV: Chapter 10
Nov 6	19\. Motion: biological, human perception	_19.MotionHumanPerception.nb _ _Weiss, Y., Simoncelli, E. P., & Adelson, E. H. (2002). Motion illusions as optimal percepts. Nat Neurosci, 5(6), 598-604. ([pdf](../../coursepapers/WeissSimonAdelNatNeu2002.pdf))_	Heeger, D. J., Simoncelli, E. P., & Movshon, J. A. (1996). Computational models of cortical visual processing. Proc Natl Acad Sci U S A, 93(2), 623-627\. ([pdf](../../coursepapers/Heeger96-reprint%20PNAS.pdf)) http://demonstrations.wolfram.com/DisappearingDotIllusion/ http://www.biomotionlab.ca/Demos/BMLwalker.html EV: Section 4.4 FV: Chapter 10

Nov 11	20\. Material perception	_20.SurfaceMaterial.nb _ V1 and lightness Doerschner, K., Fleming, R. W., Yilmaz, O., Schrater, P. R., Hartung, B., & Kersten, D. (2011). Visual motion and the perception of surface material. Current Biology, 21(23), 2010–2016.	Fleming, R. W., Dror, R. O., & Adelson, E. H. (2003). Real-world illumination and the perception of surface reflectance properties. J Vis, 3(5), 347-368\. _Adelson, E. H. (1993). Perceptual organization and the judgment of brightness. Science, 262, 2042-2044 _ Boyaci, H., Fang, F., Murray, S. O., & Kersten, D. (2007). Responses to lightness variations in early human visual cortex. Curr Biol, 17(11), 989-993 ([pdf](../../coursepapers/BoyaciCurrBiol2007.pdf))_[http://www.bilkent.edu.tr/~hboyaci/Vision/](http://www.bilkent.edu.tr/%7Ehboyaci/Vision/)_ http://web.mit.edu/persci/people/adelson/checkershadow_illusion.html http://gandalf.psych.umn.edu/users/kersten/kersten-lab/demos/transparency.html [http://gandalf.psych.umn.edu/~kersten/kersten-lab/demos/MatteOrShiny.html](http://gandalf.psych.umn.edu/%7Ekersten/kersten-lab/demos/MatteOrShiny.html)	Upload A (https://a course/v texture_ Upload F outline t ay17.mo view.php
Nov 13	21\. Texture.	_21.Texture.nb _ Freeman, J., & Simoncelli, E. P. (2011). Metamers of the ventral stream. Nature Publishing Group, 14(9), 1195-1201\. http://doi.org/10.1038/nn.2889	Heeger DJ and Bergen JR, Pyramid Based Texture Analysis/Synthesis, Computer Graphics Proceedings, p. 229-238, 1995\. ([pdf](../../coursepapers/heeger-siggraph95.pdf). EfrosTextureSynthesis.ipynb From: https://github.com/rbaravalle/efros [img2.png](Lectures/21.%20Texture/img2.png) A sample: [out2.png](Lectures/21.%20Texture/out2.png)	
Nov 18	22.Science writing (Thanksgiving week)	_22.ScienceWriting.nb_	Gopen & Swan, 1990 ([pdf](../../coursepapers/GopenSwan1990.pdf)) [UM Psychology](http://writing.psych.umn.edu/student-resources)	
Nov 20	23.Perceptual integration	_23.PerceptualIntegration.nb _	McDermott, J., Weiss, Y., & Adelson, E. H. (2001). Beyond junctions: nonlocal form constraints on motion interpretation. Perception, 30(8), 905-923\. ([pdf](../../coursepapers/McDermottbeyond_junctions.pdf)) http://www.perceptionweb.com/perception/perc0801/square.html Hillis, J. M., Ernst, M. O., Banks, M. S., & Landy, M. S. (2002). Combining sensory information: mandatory fusion within, but not between, senses. Science, 298(5598), 1627-1630.([pdf](../../coursepapers/HillisErnstBanksLandyscience02.pdf)) Ernst, M. O., & Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. Nature, 415(6870), 429-433. Stocker, A. A., & Simoncelli, E. (2008). A Bayesian model of conditioned perception. Advances in Neural Information Processing Systems, 20, 1409-1416. [IPython demo of ideal integration](http://nbviewer.ipython.org/url/gandalf.psych.umn.edu/users/kersten/kersten-lab/courses/Psy5036W2015/ArbibFinalChapterJun17_2015/Demos/ipynb/5.Cue%20Combination.ipynb) EV: Section 5	

V. High-level vision	Nov 25	24\. Object recognition I	_24.ObjectRecognition.nb _ _DiCarlo, J. J., Zoccolan, D., & Rust, N. C. (2012). How does the brain solve visual object recognition? Neuron, 73(3), 415–434. _	Liu, Z., Knill, D. C., & Kersten, D. (1995). Object Classification for Human and Ideal Observers. Vision Research, 35(4), 549-568\. ([pdf)](../../papers/LiuKnillKersten95.pdf) Tjan, B., Braje, W., Legge, G. E., & Kersten, D. (1995). Human efficiency for recognizing 3-D objects in luminance noise. Vision Research, 35(21), 3053-3069. Tanaka K (2003) Columns for complex visual object features in the inferotemporal cortex: clustering of cells with similar but slightly different stimulus selectivities. Cerebral cortex 13:90-99. Serre, T., Oliva, A., & Poggio, T. (2007). A feedforward architecture accounts for rapid categorization. Proc Natl Acad Sci U S A, 104(15), 6424-6429\. Yamins, D. L. K., Hong, H., Cadieu, C. F., Solomon, E. A., Seibert, D., & DiCarlo, J. J. (2014). Performance-optimized hierarchical models predict neural responses in higher visual cortex. Proceedings of the National Academy of Sciences of the United States of America, 111(23), 8619-8624.	
	Nov 27	25\. Object recognition II feeforward architectures	_25_Bidirectional_I.key.pdf __ Ullman, S., Vidal-Naquet, M., & Sali, E. (2002). Visual features of intermediate complexity and their use in classification. Nat Neurosci, 5(7), 682-687. _	Grill-Spector, K. (2003). The neural basis of object perception. Curr Opin Neurobiol, 13(2), 159-166. Rao, R. P., & Ballard, D. H. (1999). Predictive coding in the visual cortex: a functional interpretation of some extra-classical receptive-field effects. Nat Neurosci, 2(1), 79-87. Bullier, J. (2001). Integrated model of visual processing. Brain Res Brain Res Rev, 36(2-3), 96-107. Tenenbaum JB: Bayesian modeling of human concept learning. In Advances in Neural Information Processing Systems. Edited by Kearns MSS, Solla A, Cohn DA: Cambridge, MA: MIT Press: 1999.	
	Dec 2	26\. Object recognition III feedback architectures	_26_BidirectionalFeedback.key.pdf_ [(pdf](Lectures/26.%20ObjectRecognition_III/26_BidirectionalFeedback.pdf)) _ _	Torralba, A., Oliva, A., Castelhano, M. S., & Henderson, J. M. (2006). Contextual guidance of eye movements and attention in real-world scenes: the role of global features in object search. Psychol Rev, 113(4), 766-786. Chikkerur, S., Serre, T., Tan, C., & Poggio, T. (2010). What and where: A Bayesian inference theory of attention. Vision Research, 50(22), 2233–2247.	Upload A (https://a course/v Problem
	Dec 4	27\. Empirical evidence for bidirectional computations	27.EmpiricalEvidenceBidirectionalProcessing	Longuet-Higgins, H. C., & Prazdny, K. (1980). The Interpretation of a Moving Retinal Image. Proceedings of the Royal Society of London B, 208, 385-397. Horn BKP (1986) Robot Vision. Cambridge MA: MIT Press., chapter 17 Schrater PR, Kersten D (2000) How optimal depth cue integration depends on the task. International Journal of Computer Vision 40:73-91.	Upload a PROJECT ay17.mo view.php 4**__**
	Dec 9	28\. Vision for action, spatial layout, heading. Homegeneous coordinates.	_28.SpatialLayoutScenes.nb _ _Kalman filter notes (pdf)_		Upload y Canvas b
	Dec 11 (Last day of class)		_In Class Project Presentations_		Drafts re commer
	Dec 21				Upload F to Canva

Final Project Assignment.

Goal: This course integrates the behavioral, neural and computational principles of perception. Students often find the interdisciplinary integration to be the most challenging aspect of the course. Through writing, you will learn to synthesize results from diverse and typically isolated disciplines. By writing about your project work, you will learn to think through the broader implications of your project, and to effectively communicate the rationale and results of your contribution in words. You will do a final page research report in which you will describe, in the form of a scientific paper, the results of an original computer program on a topic in computational vision.

Your final project will involve: 1) a computer program and; 2) a 2000-3000 word final paper describing your project. For your computer project, you will do one of the following: 1) Write a program to simulate a model from the computer vision literature ; 2) Design and program a method for solving some problem in perception. 3) Design and program a psychophysical experiment to study an aspect of human visual perception. The results of your final project should be written up in the form of a short scientific paper or Mathematica Notebook, describing the motivation, methods, results, and interpretation.

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. If you do your final project using Python, you can turn your paper in as a Jupyter notebook.

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.

Completing the final paper involves 4 steps. Each step requires that you email a document to the teaching assistant.

1. **Outline (2% of grade)****.** 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. (Consult with the instructor or TA for ideas well ahead of time).

2. **Complete draft (5% of grade).** A double-spaced, complete draft of the paper must be turned in by the deadline noted in the syllabus. Papers should be between **2000** and **3000** words. In addition to the title, author and date lines, papers must include the following sections: Abstract, Introduction, Methods, Results, Discussion, and Bibliography. Use citations to motivate your problem and to justify your claims. Cite authors by name and date, e.g. (Marr & Poggio, 1979). *Citations should be original sources, not wikipedia.* Use a standard citation format, such as APA. (The UM library has information on style guides, and in particular APA style.) Papers must be typed, with a page number on each page. Figures should be numbered and have figure captions. This draft will be reviewed by your instructor and one of you class peers. **The point break down for the total 5% is: 2 pts for completing Introduction, 2 pts for completing Methods, 1 pt for completing Discussion)**

3. **Peer commentary (5% of grade)**. You will submit a written commentary **(200** to **500** words) on a complete draft of one of your class peers. The project drafts and commentaries will be anonymous. The commentary should provide feedback to improve the quality and clarity of the writing.

4. **Final draft (20% of grade) and "Cover letter" (8% of grade).** The final draft must be turned in by the date noted on the syllabus. The "Cover letter" should describe how your revision addressed comments from your peer evaluator and from your instructor. It should itemize key criticisms together with a brief description of the changes you made to your draft manuscript.

5. **Some Resources:**

6. Student Writing Support: Center for Writing, 306b Lind Hall and satellite locations (612.625.1893) http://writing.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; altering, forging, or misusing a University academic record; or fabricating or falsifying data, research procedures, or data analysis. http://www1.umn.edu/regents/policies/academic/Code_of_Conduct.html. See too: http://writing.umn.edu/tww/plagiarism/ and*http://writing.umn.edu/tww/plagiarism/definitions.html