

**Psych 217: Vision
Winter 2021**

Wed: 1:00 - 3:50 PM

Prerequisites: Basic math (matrix algebra, calculus, probability, elementary geometry).

Instructor: **Dr. Zygmunt Pizlo (zpizlo@uci.edu)**

The course will focus on 3D visual perception with emphasis on mathematical and computational models of human vision. PDFs of reading materials will be available on the course web site.

There will be biweekly projects where students will implement algorithms for visual computations.

Week 1: Euclidean, similarity, affine, and projective groups. Invariants. Geometrical optics. Calibrated camera.

Mundy, J.L. & Zisserman, A. (1992) Geometric invariance in computer vision. MIT Press: Cambridge, MA (Chapter 1: Introduction – towards a new framework for vision).

Mundy, J.L. & Zisserman, A. (1992) Geometric invariance in computer vision. MIT Press: Cambridge, MA (Chapter 23: Projective geometry for machine vision).

Burns J.B., Weiss, R.S. & Riseman E.M. (1992) The non-existence of general-case view-invariants. In: Mundy, J.L. & Zisserman, A. (Eds.) Geometric invariance in computer vision. MIT Press: Cambridge, MA (pp. 120-131).

Pirenne M.H. (1975) Vision and art. In: Carterette E.C. & Friedman M.P. (Eds.) Handbook of Perception, vo. V: Seeing. NY: Academic Press (pp. 433-490).

Week 2: Perception viewed as an inverse problem.

Poggio T., Torre V. & Koch C. (1985) Computational vision and regularization theory. Nature 317, 314-319.

Chater, N. (1996). Reconciling simplicity and likelihood principles in perceptual organization. Psychological Review, 103, 566–581.

Pizlo, Z. (2001) Perception viewed as an inverse problem. Minireview. Vision Research 41, 3145-3161.

Week 3: Nativism vs. empiricism.

Hess E.H. (1956) Space perception in the chick. Scientific American 195, 71-80.

Hubel D.H. & Wiesel T.N. (1963) Receptive fields of cells in striate cortex of very young, visually inexperienced kittens. Journal of Neurophysiology 26, 994-1002.

Rock I. & Harris C.S. (1967) Vision and touch. *Scientific American* 216, 96-104.

Hochberg J. & Brooks V. (1962) Pictorial recognition as an unlearned ability: a study of one child's performance. *American Journal of Psychology* 75, 624-628.

Linden D.E.J., Kallenbach K., Heinecke A., Singer W. & Goebel R. (1999) The myth of upright vision. A psychophysical and functional imaging study of adaptation to inverting spectacles. *Perception*, 1999, 28, 469-481.

Week 4: Shape perception and shape constancy experiments.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, 171 (3972), 701–703.

Mishkin, M., Ungerleider, L.G. & Macko, K.A. (1983) Object vision and spatial vision: two cortical pathways. *Trends in Neurosciences* 6, 414-417.

Rock I. & DiVita J. (1987) A case of viewer-centered object perception. *Cognitive Psychology* 19, 280-293.

Biederman I. & Gerhardstein P.C. (1993) Recognizing depth rotated objects: evidence and conditions for three-dimensional view-point invariance. *Journal of Experimental Psychology: Human perception & Performance* 19, 1162-1182.

Li, Y. & Pizlo, Z. (2011) Depth cues vs. simplicity principle in 3D shape perception. *Topics in Cognitive Science* 3, 667-685.

Week 5: Monocular shape recovery based on a minimum principle.

Hochberg J. & McAlister E. (1953) A quantitative approach to figural "goodness". *Journal of Experimental Psychology* 46, 361-364.

Attneave F. & Frost R. (1969) The determination of perceived tridimensional orientation by minimum criteria. *Perception & Psychophysics* 6, 391-396.

Perkins D.N. (1976) How good a bet is good form. *Perception* 5, 393-406.

Leclerc, Y. G., & Fischler, M. A. (1992). An optimization-based approach to the interpretation of single line drawings as 3D wire frames. *International Journal of Computer Vision*, 9, 113–136.

Week 6: Symmetry: Redundancy and invariance. Restoring one-to-one mapping between a 3D shape and its 2D image. Vanishing point.

Barlow, H. & Reeves, B.C. (1979) The versatility and absolute efficiency of detecting mirror symmetry in random dot displays. *Vision Research*, 19, 783-793.

Vetter, T. and Poggio, T. (1994) Symmetric 3-D objects are an easy case for 2-D object recognition. *Spatial Vision* 8, 443–453.

Feldman J. & Singh M. (2006) Bayesian estimation of the shape skeleton. *PNAS* 103, No. 47, 18014-18019.

Sawada, T. (2010) Visual detection of symmetry of 3D shapes. *Journal of Vision* 10(6), 1-22.

Li, Y., Sawada, T., Shi, Y., Steinman, R.M. & Pizlo, Z. (2013) Symmetry is the sine qua non of shape. In: S. Dickinson & Z. Pizlo (Eds.), *Shape perception in human and computer vision*, London, Springer. (pp. 21-40).

Week 7: Symmetry correspondence problem.

Sawada, T., Li, Y. & Pizlo, Z. (2011) Any pair of 2D curves is consistent with a 3D symmetric interpretation. *Symmetry* 3, 365-388.

Sawada T., Li Y. & Pizlo Z. (2014) Detecting 3-D mirror symmetry in a 2-D camera image for 3-D shape recovery. *Proc. IEEE*, 102, 1588-1606.

Week 8: Binocular vision. Disparity of features vs. disparity of objects. Multiple views.

McKee S.P., Levi D.M. & Bowne S.F. (1990) The imprecision of stereopsis. *Vision Research* 30, 1763-1779.

Longuet-Higgins H.C. (1981) A computer algorithm for reconstructing a scene from two projections. *Nature* 293, 133-135.

Pizlo Z., Li Y. & Francis G. (2005) A new look at binocular stereopsis. *Vision Research* 45, 2244-2255.

Li, Z., Sawada, T., Shi, Y., Kwon, T. & Pizlo, Z. (2011) A Bayesian model of binocular perception of 3D mirror symmetric polyhedra. *Journal of Vision*, 11(4):11, 1-20.

Michaux, V., Jayadevan, V., Delp, E. & Pizlo, Z. (2016) Figure-ground organization based on 3D symmetry. *Journal of Electronic Imaging* 25(6).

Jayadevan, V., Sawada, T., Delp, E. & Pizlo, Z. (2018) Perception of 3D symmetrical and nearly symmetrical shapes. *Symmetry* 10, 344.

Week 9: Symmetry in physics. Least-action principle. Noether's theorem.

Wigner, E. P. (1964). Symmetry and conservation laws. *Proceedings of the National Academy of Sciences*, 51, 956–965.

Foster, D. H. (1978). Visual apparent motion and the calculus of variations. In E. L. J. Leeuwenberg & H. F. J. M. Buffart (Eds.), *Formal theories of visual perception* (pp. 67–82). New York, NY: Wiley.

Poggio, T., & Koch, C. (1985). Ill-posed problems in early vision: From computational theory to analogue networks. *Proceedings of the Royal Society of London B*, 226, 303–323.

Stocker, A. A. (2006). Analog integrated 2-d optical flow sensor. *Analog Integrated Circuits and Signal Processing*, 46, 121–138.

Ben-Yosef, G., & Ben-Shahar, O. (2012). Tangent bundle curve completion with locally connected parallel networks. *Neural computation*, 24 (12), 3277–3316.

Pizlo, Z. (2019) Unifying physics and psychophysics on the basis of symmetry, least-action \approx simplicity principle, and conservation laws \approx veridicality. *American Journal of Psychology* 132, 1-25.

Week 10: Pyramid algorithms for vision.

Campbell, F.W. & Robson, J.G. (1968) Application of Fourier analysis to the visibility of gratings. *J. Physiology* 197, 551-566.

Rosenfeld, A., & Thurston, M. (1971). Edge and curve detection for visual scene analysis. *IEEE Transactions on Computers*, C-20, 562-569.

Tanimoto, S. & Pavlidis, T. (1975) A hierarchical data structure for picture processing. *Computer Graphics and Image Processing* 4, 104-119.

Adelson, E.H., Anderson, C.H., Bergen, J.R., Burt, P.J. & Ogden, J.M. (1984) Pyramid methods in image processing. *RCA Engineer* 29, 33-41.

Pizlo, Z., Rosenfeld, A. & Epelboim, J. (1995) An exponential pyramid model of the time course of size processing. *Vision Research*, 35, 1089-1107.

Pizlo, Z. & Stefanov, E. (2013) Solving large problems with a small working memory. *Journal of Problem Solving* 6(1), 34-43.