The Primate Early Visual System

The primate early visual system is comprised of the cornea, the lens and the retina. The retina has a number of layers, including the photoreceptors, bipolar cells and retinal ganglion cells.

ISETBio: Image Systems Engineering Toolbox for Biology

ISETBio is based on ISET, the Image Systems Engineering Toolbox. The processing pipeline consists of computational simulations of a hyperspectral scene and a particular display device, followed by the optics of the cornea and the lens, the transduction in the photoreceptors and further processing in the bipolar cells and retinal ganglion cells. The final stage in the pipeline is the computational observer, a linear classification that separates signal trials from noise trials.

The Scene and Display: Changing the Illuminant Spectrum

ISETBio allows for modeling of the spectra of the reflectance properties of object surfaces as well as the illuminant. Here, the spectrum of the illuminant is changed, and the reflected light from each object changes as a consequence.

Cone Optics: The Point Spread Function

The hyperspectral representation of the stimulus on a display device is projected upon the surface of the retina through the cornea and lens. ISETBio simulates the PSF for different cone types, which results in S cones with wider PSFs than L and M cones.

Cone Mosaic: Isomerizations and Photocurrent

The cone mosaic is generated with the appropriate ratio of L, M and S cones, and the proper spacing for a given eccentricity. We employ a biophysical model of the cone photocurrent generation that captures nonlinear dynamics over time across image patches of greatly varying mean luminance.

The Bipolar and RGC Mosaics

The cone photocurrent is fed into a model of the bipolar cell mosaic, which captures spatial nonlinearities that improve the accuracy of responses to natural scenes. The RGC mosaic is modeled with a coupled linear-nonlinear-Poisson model that outputs spikes. ISETBio captures a range of nonlinearities through the early visual system.

The Computational Observer

The computational observer method has some similarity to the ideal observer, but is more empirical. Noise is simulated for each trial, and summary measurements of each trial can be fed into a linear classifier to find the threshold given the structure of the model.

Threshold Measurements with the Computational Observer

A classical experiment in the measurement of perceptual thresholds is that of the Vernier stimulus. We can simulate the experimental pipeline by measuring the responses to a Vernier stimulus with and without an offset. The accuracy of the linear classifier can be used to generate a prediction for physiological or psychophysical experiments.

References