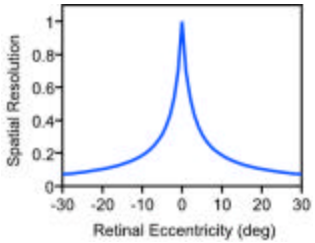
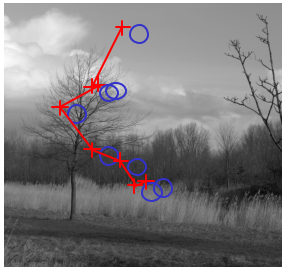
Local Luminance and Contrast in Natural Scenes: Implications for Understanding Visual Systems that Make Saccadic Eye Movements

W.S. Geisler[1,2], R.A. Frazor[1,2], R.G. Raj[1,3], A.C. Bovik[1,3], V. Mante[4], M. Carandini[4]

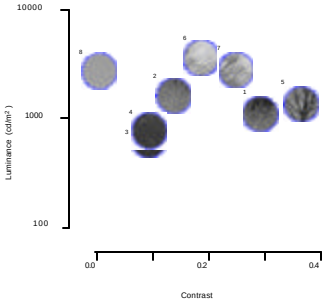
[1]Center for Perceptual Systems, University of Texas at Austin
[2]Department of Psychology, University of Texas at Austin
[3]Department of Electrical and Computer Engineering, University of Texas at Austin
[4]The Smith-Kettlewell Eye Research Institute, San Francisco



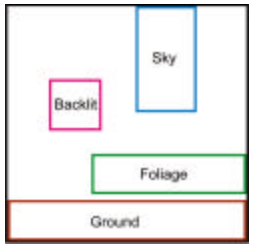
1. The relative spatial resolution of the human visual system as a function of retinal eccentricity (distance from the fovea). Varying spatial resolution allows a large field of view and good acuity, with limited neural resources. However, frequent saccadic eye movements are required.



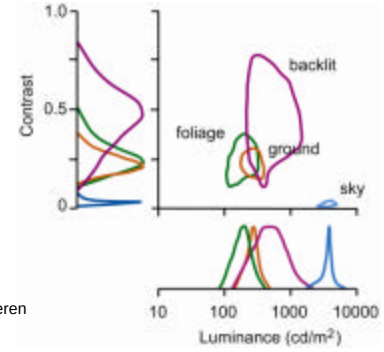
2. A typical sequence of fixations of a natural scene (red plusses). The duration of each fixation is in the range of 200-300 ms. The blue circles show the series of stimuli that would fall upon an arbitrary receptive field with a diameter of 1 deg.



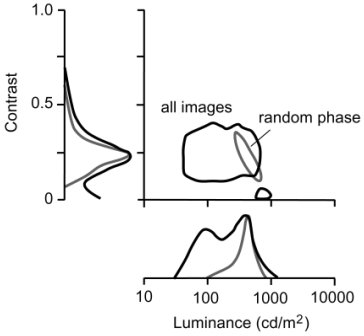
3. The luminance and contrast of the sequence of stimuli falling on the arbitrary 1 deg receptive field in Fig. 2.



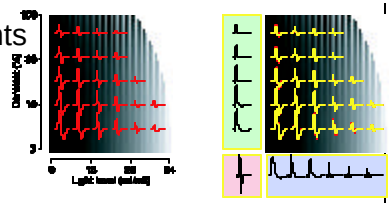
4. Local luminance and contrast statistics were measure in 300 calibrated natural images (van Hateren & van der Schaaf, 1998). The statistics were measured for whole images and for their major constituents. Samples of the constituents were obtained from regions selected by hand from the 300 images. This figure shows example regions for Fig. 2.



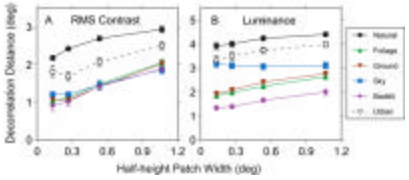
5. Marginal and joint distributions of local contrast and luminance within the major constituents of natural images. The contours are 95% confidence bounds. The correlations are low: foliage = +0.2, ground = -0.1, backlit foliage = -0.2, sky = 0.0.



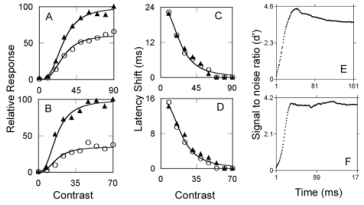
6. Marginal and joint distributions of local contrast and luminance in natural images and in natural images with randomized phase. The correlation for natural images is low: -0.2. The correlation for natural images with random phase is high: -0.8.



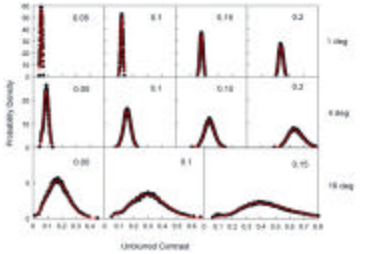
7. Is the independence (low correlation) of local luminance and contrast in natural images matched by independence of the adaptation mechanisms? These measurements in the cat LGN suggest that they are. The temporal impulse responses of LGN neurons (red) are predicted (yellow) by separable mechanisms.



8. Distance between image patches in natural images where correlation falls to an average of 0.25 as a function of patch size. These distances are generally smaller than the average saccade length, implying that contrast and luminance gain control should be very rapid if they are to be of value during saccadic inspection.



9. Some of the evidence that contrast gain control is fully operational within 20 ms of stimulus onset in monkey V1. The half saturation contrast and response latency are the same for optimal and non-optimal stimuli. Detectability(d') saturates within 100 ms. Albrecht, Geisler, Frazor & Crane (2001).



10. Example posterior probability densities of contrast in un-blurred natural images, conditional on the observed contrast and retinal eccentricity. The data are based on applying typical human CSFs to 300 natural images. The smooth curves are best fitting "skewed Gaussian" distributions, which have a different s above and below the mode.

Mode:

$$u(\varepsilon,c) = k\varepsilon c + c$$

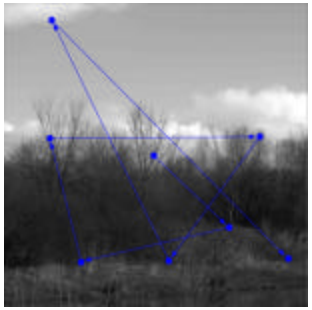
Average Standard Deviation:

$$\bar{\sigma}(\varepsilon,c) = k\varepsilon c$$

Differential Entropy:

$$h(\varepsilon,c) = \frac{1}{2}\log_2\left(2\pi e\left[(k\varepsilon c)^2 + \sigma_0^2\right]\right)$$

11. Model of the posterior probability density of local image contrast, conditional on the observed contrast *c* and eccentricity *e*. The value of *k* is approximately 0.1. This model fits the data quite well.



12. A simple but potentially efficient strategy for choosing fixation points is to pick the next fixation so as to maximize the expected reduction in local contrast uncertainty (entropy) for the entire scene. Shown is an example of fixations picked in this way.