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Models of Neural Systems, WS 2009/10
Project 8: Complex cells tuned to disparity
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Background

The visual cortex contains cells sensitive to binocular disparity i.e. difference in image location of an object seen by the left and right eyes, resulting from the eyes' horizontal separation. The brain uses binocular disparity to extract the depth information for stereotopic vision. In the project, you will model receptive fields of such cells and analyse their responses to gratings and natural images.

Problems

1. Construct a model simple cell that sums inputs from both eyes. The receptive field of each eye is described by a Gabor wavelet:

$$\rho(x, y) = \cos(fx' - \phi) \exp\left(-\frac{x'^2 + y'^2}{2\sigma^2}\right),$$

where $x' = x\cos\theta + y\sin\theta$; $y' = y\cos\theta - x\sin\theta$, f is the cell's preferred spatial frequency, θ is its preferred orientation, ϕ is its phase and σ describes the size of the receptive field.

2. Calculate the response of a simple cell to gratings:

$$I_{L,R}(x, y) = \cos(Kx + \Phi_{L,R}),$$

where I_L and I_R are the inputs to the left and right eyes respectively; Φ_L, Φ_R are phase shifts of the gratings and K is the spatial frequency. Take $\Phi_L = \Phi_R = \Phi$, $f = K = 2$, $\sigma = 1$. Plot the tuning curve as a function of Φ.

3. Construct a complex cell that sums squares of responses of two simple cells: $L_C = L_1^2 + L_2^2$. The receptive fields of both simple cells should be similar but differ in the phase (for example $\phi_1 = 0$, $\phi_2 = \pi/2$).

4. Show that the complex cell is tuned to disparity in the images, $\Phi_L - \Phi_R$, but is independent of the absolute spatial phase of the grating, $\Phi_L + \Phi_R$. Plot the response tuning curve as a function of disparity.

5. Use the above model, estimate the disparity maps in natural stereoscopic images. To this end, calculate the responses of complex cells with receptive fields centered at each pixel of the image (*Hint:* you can use spatial convolution). Plot obtained disparity maps for different preferred frequencies f and preferred orientations θ. (You can download some stereoscopic images from `http://vision.middlebury.edu/stereo/`).

Literatur

[1] P Dayan, LF Abbott, "Theoretical neuroscience", MIT Press 2001

[2] GC DeAngelis, I Ohzawa, RD Freeman, "Depth is encoded in the visual cortex by a specialized receptive field structure", Nature 352: 156-159 (1991)

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