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Models of Neural Systems I, WS 2009/10
Computer Practical 4
Solutions to hand in on: November, 16th, 2009

Visual receptive fields

Exercises

1. A commonly used stimulus for the recordings from the visual system is a sinusoidal grating:

$$s(x, y) = A\cos(Kx\cos\Theta + Ky\sin\Theta - \Phi) \quad (1)$$

where x, y are the spatial coordinates, K is the spatial frequency, Θ is the orientation, Φ is the spatial phase and A is the contrast amplitude.

   (a) Approximate the visual field (x, y) with a 2-dimensional grid of uniformly-sampled points: $(x_i, y_i) = (-x_0 + i\Delta x, -y_0 + j\Delta y)$ for $i = 0, 1, \ldots, \frac{2x_0}{\Delta x}$ and $j = 0, 1, \ldots, \frac{2y_0}{\Delta y}$ where Δx, Δy are bin sizes and x_0 and y_0 are the stimulus extents (in degrees of visual field). Take $x_0 = 5°$, $y_0 = 5°$.

   Hint: You can use `pylab.meshgrid` to generate such a grid.

   (b) Plot the grating on the grid for the following parameters: $\Theta = 0$, $\Phi = 0$, $K = \pi\frac{1}{\text{degree}}$, $A = 1$. Use the `pylab.imshow` function to show a 2-dimensional map.

   (c) Vary the orientation Θ and the spatial frequency K and plot the resulting maps.

2. **A model of receptive fields**. A mathematical approximation of the receptive field of a simple cell is provided by a Gabor function:

$$D_s(x, y) = \frac{1}{2\pi\sigma_x\sigma_y}\exp\left(-\frac{x^2}{2\sigma_x^2} - \frac{y^2}{2\sigma_y^2}\right)\cos(kx - \phi) \quad (2)$$

where k is the preferred spatial frequency, ϕ is the preferred spatial phase, σ_x, σ_y are the receptive field sizes.

(a) Implement a Gabor function as a model of the receptive field of a V1 simple cell with a preferred spatial frequency $k = \pi \frac{1}{\text{degree}}$, preferred spatial phase $\theta = 0$ and receptive field size $\sigma_x = 2°$, $\sigma_y = 1°$.

(b) Calculate the response of a cell with such a receptive field to the grating from exercise 1b using a simple linear model:

$$L_s = \sum_{i=0}^{\frac{2x_0}{\Delta x}} \sum_{j=0}^{\frac{2y_0}{\Delta y}} D_s(x_i, y_i) s(x_i, y_i) \Delta x \Delta y \tag{3}$$

3. **Tuning Curve**. A tuning curve describes the dependence of the neuronal response on a parameter of the stimulus such as spatial frequency, orientation or phase. Plot the neuronal response L_s to the grating from the exercise 1b as a function of:

(a) stimulus orientation Θ,

(b) ratio of the stimulus' spatial frequency to the cell's preferred value K/k,

(c) stimulus' spatial phase Φ.

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