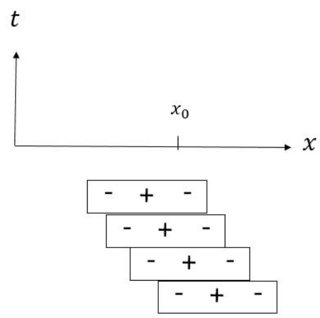
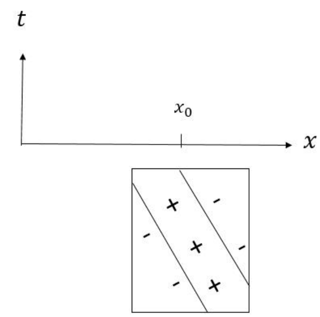
Questions

1. Compare the two XT slices below. For both cells, the response at $t = 0$ depends on the intensities in the past. For one cell, the receiptive field at different times in the past is shifted and the profile *within* the shifting receptive field is constant. For the other, the receptive field is fixed but the profile varies over time.





   Assume the cell's Y component is constant over some range of y (i.e. a vertically oriented cell – coming out of the page). The left cell can be described as a set of shifted vertical cosine Gabors. How can we describe the receptive field profile of the right cell?

2. We have seen that a space-time Gabor can be defined by a 3D sine wave function multiplied by a Gaussian window. Such a cell is often used in modelling the *linear* response of orientation and motion direction tuned cells in V1, namely by taking the inner product of the Gabor with the XYT image at some position and time (x_0, y_0, t_0).

   The Gabor model is mathematically simple. Can you think of any obvious problems with it for the case of motion?

3. The cells illustrated in the lecture were all simple cells in that they had a well defined + or - region in XYT. How could one define motion sensitive complex cells ?

Solutions

1. The cell on the right also has vertical orientation (i.e. extended in the Y direction). But its profile in the X direction changes over time. If we take three time slices, we get a sine Gabor, a cosine Gabor, and a sine Gabor, where the two sine Gabor profiles are of opposite polarity. Another way to describe the receptive field profile of the right cell is that it varies continuously over time, such that the phase angle ϕ of the sinusoid underlying the Gabor $\sin(kx + \omega t + \phi)$ increases over time. Think of a sine wave moving within a fixed Gaussian window.

2. One problem that I mentioned in class is that the Gaussian window has infinite temporal extent, at least in theory. This would imply that the window can reach into the future, so the cell's response at time t_0 depends on images that haven't been measured yet.

   Another problem which is less fundamental – but still a problem if you care about the fit – is that the Gabor's temporal sensitivity window is symmetric about some past time, namely the mean of the Gaussian window. There is no reason why the temporal independence should be symmetric like that, and indeed real measurements suggest that it is not symmetric.

3. Take a cosine and sine Gabor pair which are defined by the same spatial frequencies (k_x, k_y) and temporal frequency ω. Each of these Gabors would define the same preferred spatial orientation in each time slice and would define the same speed of that orientation over time (normal velocity). We could define a complex cell just as we did in 2D, namely take the sum of the squared values of these two linear responses. The resulting complex cell would have a large response for that same preferred orientation and speed. The main differences between the complex and simple cell is that the complex cell would give a good response regardless of where the oriented structure was exactly within the Gaussian window (edge vs. line and polarity independent).