Questions

1. Let $[\ ]_+$ denote the half-wave rectification operation, so $[r]_+ \equiv max(r, 0)$.

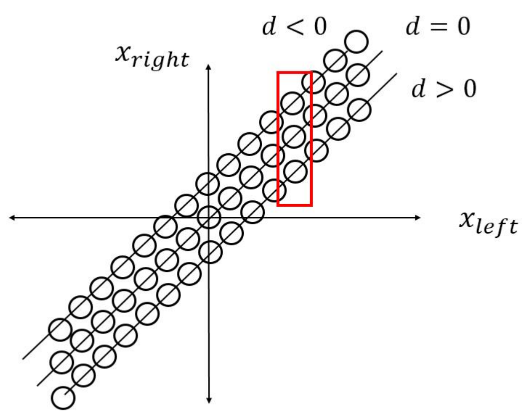
   In the lecture notes, the response of a complex cell was modelled as the square root of the sum of squared *linear* responses of two simple cells, which in turn were modelled as a sine and a cosine Gabor:

   $$\sqrt{< cosGabor(x - x_0, y - y_0), I(x, y) >^2 + < sinGabor(x - x_0, y - y_0), I(x, y) >^2)}$$

   However, this model is not biologically plausible since cells cannot give negative responses and so one needs a half-wave rectification.

   How could one rewrite the model using simple cell responses that have been rectified to remove negative responses? Hint: you will need four cells rather than two.

2. In the illustration below, the cells in each column are non-overlapping. What is the interpretation of this illustration, in terms of the maximum and minimum disparity of the cells versus the receptive field width (x size) of the cells?



3. Small binocular complex cells tend to be tuned to a small range disparities and large binocular complex cells tend to be tuned to a large range of disparities. Moreover, at small *eccentricities* (near the fovea), cells tend to have small receptive fields, whereas at large eccentricities cels tend to have large receptive fields.

   Using circles as above to illustrate the size and location of receptive fields, make a *sketch* of disparity space (x_l, x_r) that illustrates how cell receptive field size (circle size) varies with disparity and eccentricity.

4. Vertically oriented Gabors are more reliable for measuring binocular disparity than obliquely or horizontally oriented Gabors. What is the intuition for this?

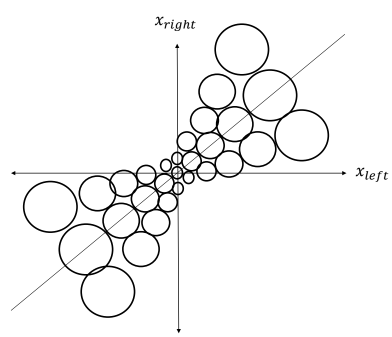
Solutions

1. We need two cosine Gabors and two sine Gabors. The two cosine Gabors would be identical except for a sign flip at each point, and similarly with the sine Gabors. (Formally, this is equivalent to adding a phase shift of 180 degrees to the underlying cosine or sine function, respectively.)

   If r_c is the cosine Gabor's *linear* response, which can be possible positive or negative, then the square of the linear response of the Gabor can be written using rectified cosine Gabors like this:
   $$r_c^2 = [r_c]_+^2 + [-r_c]_+^2$$
   The same can be done for the sine Gabor. Then the model in the lecture notes can be written as the sum of the half wave rectified responses of four cells:
   $$r_s^2 + r_c^2 = [r_s]_+^2 + [-r_s]_+^2 + [r_c]_+^2 + [-r_c]_+^2.$$
   This is exactly what was done in slide 7 of the lecture.

2. When the cells in each column are non-overlapping, it means that the receptive fields in the right eye are non-overlapping. The disparity of the central cell in each column lies along the diagonal (disparity = 0). Thus the two off diagonal cells in each column represent disparities that are greater in magnitude that the width of each cell.

3. The size of receptive fields increases as you move away from the $d = 0$ line and as you move away from the origin. The fovea is the origin $x_{left} = x_{right} = 0$.



4. For the intuition, hold up a wire horizontally in front of you: if you shift the wire left and right only, then its image on your retina will not change much. What does this have to do with the question? Well, horizontally oriented cells respond best to horizontally oriented edges or lines. But such oriented intensity structures do not provide useful information for binocular disparity since, by definition, they do not vary in the direction of the binocular disparity. So the *responses* of horizontal cells will not vary much when *any image* image shifts horizontally. This means that the cell responses contain little information about the horizontal position of points in the image.

   There is some still information about disparity from oblique orientations, but quantifying this would take us into technical issues that would be inappropriate now. Next lecture we will cover closely related issues when we discuss image motion.