Questions

1. (a) What is the depth increment that corresponds to 1 arcmin of disparity at a viewing distance of 1 meter? i.e. The eyes are converging at this distance.

   (b) According to the plot shown in the lecture (slide 29), the threshold for detecting a sinusoidal depth corrugation can be as low as a few arc seconds. What is the depth increment for a disparity of 4 arcsec at a viewing distance of 1 m?

   FYI, from the slide, the peak happens at about 0.5-1 cycle per deg.

2. A common observation made in the winter on overcast days is that the snow appears to be brighter than the sky. For example, when you stand in a snow-covered field and you look at the horizon, the ground seems to be brighter than the sky above the horizon – and the sky itself seems to be uniformly bright. This would seem to defy the laws of physics, since the ground is reflecting the skylight, so the ground obviously can't be brighter the sky. What's going on here?

   How could you explain this phenomenon in terms of contrast sensitivity?

3. Consider a surface whose depth varies sinusoidally in the x direction but is constant in the y direction. Suppose the surface is defined by random dots, displayed on a stereo monitor, such that corresponding dots in the left and right eye images produce retinal disparities

$$d(x, y) = a \ \sin(kx).$$

   Describe a psychophysical experiment that measures

   (a) discrimination thresholds to amplitude as a function of a reference amplitude a, for a fixed value of spatial frequency k.

   (b) discrimination thresholds for spatial frequency as a function of reference frequency k, for a fixed value of amplitude a.

4. Consider the task of detecting a 2D cosine intensity function in noise. The task is to say whether the cosine function has a horizontal orientation or vertical orientation. What would be the advantage of using this task, instead of just asking subjects if they see the cosine function or not (and showing a cosine function always of the same orientation, but at a range of contrasts including some very low ones) ?

5. Consider the claim that, "for surfaces that are near to the eye (say 30 cm), discrimination thresholds for slant angle from binocular stereo *increase* as surface slant increases". Note that this dependence is opposite to what happens with slant from texture, where thresholds decrease as slant increases.

   (a) Explain what this claim means by describing a particular psychophysical task and a subject's performance in this task.

   (b) How might this claim relate to Panum's fusional area?

Solutions

1. (a) An arcminute is 1/60 of a degree. Suppose the distance between the eyes is 0.06 m. Then, the depth increment ΔZ can be derived from the following equation:

$$disparity\ in\ radians = T_X(\frac{1}{Z_{vergence}} - \frac{1}{Z_{vergence} + \Delta Z})$$

Simplify the term in brackets by approximating a derivative:

$$\frac{\frac{1}{Z + \Delta Z} - \frac{1}{Z}}{\Delta Z} \approx \frac{d}{dZ}(\frac{1}{Z}) = -\frac{1}{Z^2}$$

and so

$$\frac{1}{Z + \Delta Z} - \frac{1}{Z} \approx \frac{\Delta Z}{Z^2}$$

and so

$$disparity \approx T_X \frac{1}{Z^2} \Delta Z$$

Since the disparity is given to be 1/60 of a degree, it is $\frac{1}{60}\frac{pi}{180}$ radians. since $Z_{vergence} = 1$ and $T_X = .06$, we have

$$\frac{1}{60}\frac{\pi}{180} = .06 \Delta Z$$

so $\Delta Z \approx 5mm$.

(b) 4 arcsec is 1/15 of an arcmin. For such a small ΔZ, the relation between depth and disparity is nearly linear, so we can just multiply the answer for (a) by $\frac{1}{15}$. So the corresponding depth increment that subject can detect is about $\frac{1}{3}$ mm. That is quite amazing if you think about it.

2. Although the sky might appears to be nearly uniformly bright, in fact it is not. On an overcast day, the zenith (high overhead) directions of the sky are about 3 times brighter than the horizon. Given this fact, consider how the luminance (intensity) from the sky compares to the luminance of the light reflected from the snow. The luminance of the snow is a weighted average of the luminances from the different directions of the sky. Thus, the snow's luminance has a value between the sky's zenith luminance (max) and the sky's horizon luminance (min) i.e. the snow has a greater luminance than the sky's horizon.

How does the above explain the visual effect in the question? The transition from the (darker) sky horizon to (brighter) sky zenith happens over 90 degrees of visual angle, which is a very low spatial frequency. Our visual systems have very poor contrast sensitivity at low spatial frequencies, so we don't see this transition. i.e. The sky looks uniformly bright, from horizon to zenith. So what happens is that we correctly perceive the sky to be darker than the snow around the horizon, but we fail to perceive that the sky brightens significantly at the zenith.

3. (a) For any fixed amplitude a, the task could be to compare a standard (or reference) surface

$$d(x, y) = a\ \sin(kx)$$

to a test surface

$$d(x, y) = (a\ + \Delta a) \sin(kx)$$

and decide which surface has greater amplitude in the depth variations.

There would be a psychometric function for each value of a. It would show the percentage of responses "test has greater amplitude than standard" as a function of Δa. The threshold value of Δa would be defined as the value of Δa where the response occurs some percentage (say 75) of the time.

Varying the reference amplitude a would give a set of thresholds.

(b) Consider a standard (or reference) surface

$$d(x, y) = a\ \sin(kx)$$

and a test surface

$$d(x, y) = a \sin((k + \Delta k)x).$$

The task would be to decide which of these surfaces has greater spatial frequency.

The parameters a and k would be fixed, and the psychometric function would plot the percentage response "test has greater frequency than standard" as a function of Δk. Define the threshold value of Δk to be the value where the percentage response is say 75. Varying k would give a set of thresholds (for the fixed a).

4. If you just ask subjects to say if they see the cosine function or not, then subjects will have to adopt some arbitrary internal criterion for when they answer 'yes' and when they answer 'no'. (Remember: near threshold levels, subjects are not sure if you see it. There are, by definition, uncertain about their response near threshold values.) Some subjects might need to be more sure they see it than others, before they say 'yes' and would respond 'yes' less frequently just because of a *decision threshold*, rather than a *perception* threshold. It is believed that by forcing subjects to choose between two stimuli (called "two alternative forced choice"), you can reduce the effects of this decision threshold.

5. (a) The task is to distinguish the slopes (measured in slant angle) of different planar surfaces. Slant angle can go from $\sigma = 0$ (frontoparallel) to 90 degrees (infinite slope).

For each standard slant σ, the task is to decide whether a standard is more or less slanted than a test slant $\sigma + \Delta\sigma$, where $\Delta\sigma > 0$. The standard and test could be shown say one after the other, and the subject would be asked to identify which was more slanted. The psychometric curve could plot percent correct as a function of $\Delta\sigma$. Threshold could be the $\Delta\sigma$ such that subject was correct 75 % of the time.

(b) If the surface is more slanted, then fewer points will fall into Panum's fusional area. Only points that fall into Panum's fusional area give reliable slant information *from their binocular disparity*, and hence there are fewer such points when slant is large. Thus, slant from stereo is less reliable when slant is large. (This statement holds regardless of whether the slant is in the x direction on in the y direction. In the figure below, the slant is in the y direction, like looking down at the ground.)

Two eyes

Panum's
area