

Instructions: 50 min closed book, notes. Answer all questions in the bluebook provided.

1. (a) Explain how computation of an epipolar line facilitates stereopsis.

It reduces the correspondence search from 2-D to 1-D.

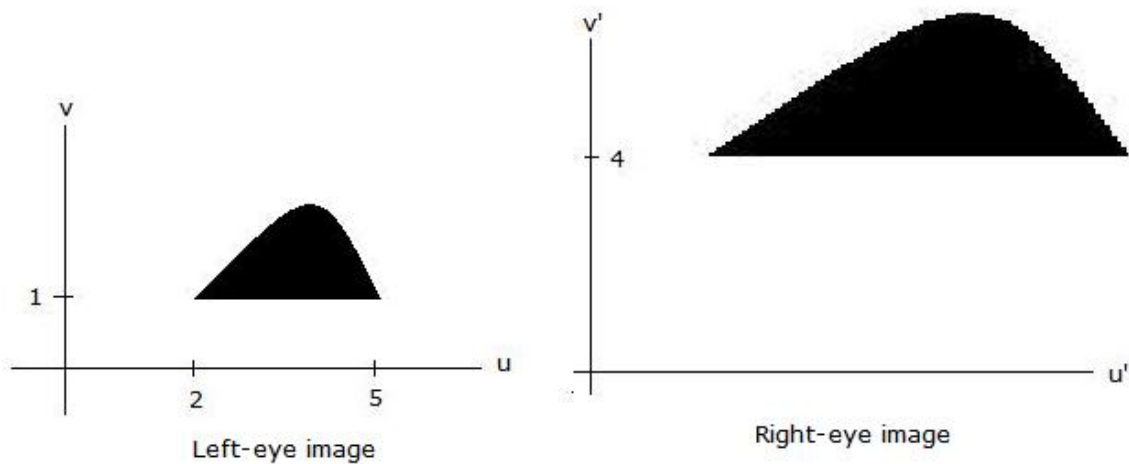
(b) The Longuet-Higgins Equation for a given camera model is $u^T F u' = 0$ where the fundamental matrix F is

$$F = \begin{bmatrix} 0 & 0 & 6 & 0 & -1 & -1 & 1 & 0 \\ 0 & 0 & 6 & 0 & -1 & -1 & 1 & 0 \end{bmatrix}$$

The left-eye image, corresponding to the unprimed vector u in the Longuet-Higgins Equation above, is shown below. The visible black object has a straight edge in the image at $v=1$ which is of length 3. The same straight edge is visible in the right-eye image at $v'=4$. What is its length?

$$u^T F u' = 0 \implies 6u u' - u - u' = 0 \implies u u' = \frac{u + u'}{6}$$

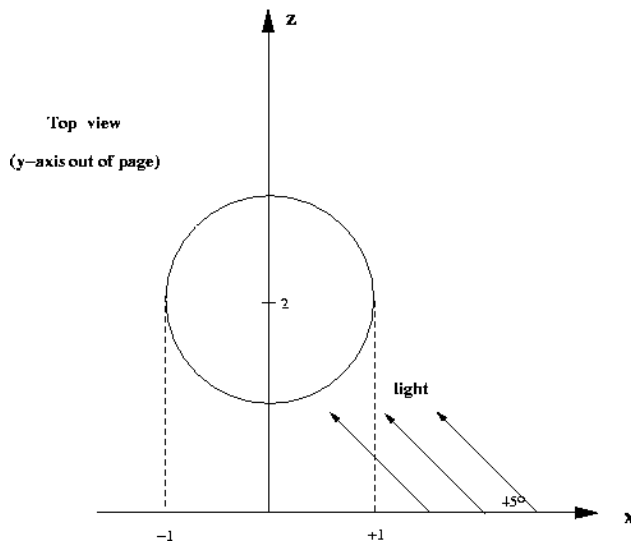
One end of the line is at $u=5, v=1, v'=4$ so $u' = 33$. The other is at $u=2, v=1, v'=4$ so $u'=15$. The length of the line in the right-eye image is $33-15=18$.



2. Vassallo's navigation scheme has two parts: detection of landmarks, and visual servoing (corridor-following) between landmarks. Suppose you are a bee who needs to find flowers and then return to the hive. Doorways won't work for landmarks, and corridor-following surely will not work for visual servoing since there are no corridors outside. Describe how you could use the available visual cues, including the sun and shadows, to apply Vassallo's two-part navigation scheme to the bee navigation problem. Describe how the bee would behave from the moment it left its hive, to the moment it arrived back. What visual information would it acquire, and how might the bee use it?

There are many possible solutions, here is perhaps the simplest. The bee could leave the hive flying in a straight line, visually servoing to maintain the straight flight path by keeping the sun at a constant view angle, or if the sun is not in the field of view, keeping the angle of the shadows constant. When the bee decides to turn, it should memorize a prominent feature of whatever view it sees, ie. a landmark. It should then continue on a straight line, capturing a landmark each time it turns and flying in a straight line between landmarks. When it has completed its "outbound" journey and wishes to return, it should search visually until it finds the most recent landmark, then fly directly towards it, again using the sun and shadows for visual servoing to maintain the straight flight path. When it reaches the next landmark, it should search visually for the next one and repeat until it is safely back in the hive. Note that on the outbound leg, the best time for the bee to look at the landmark is after it has passed it. That is the view it will see flying back.

3. A cylinder of radius 1 centered at $(x,y,z)=(0,0,2)$ with axis parallel to the y axis (see the diagram) is viewed orthographically in the image plane $z=0$. A light source at infinity produces rays which make a 45° angle to the x -axis as shown.



(a) Does the value of x at which this image is brightest depend on whether the cylinder's reflectance is Lambertian vs. specular? Explain.

Yes. If Lambertian, x is the point where the surface normal is 45° . If specular, x is the point where the angle of incidence equals reflection takes us to x , which is where the surface normal is 22.5° away from the z -axis.

(b) Find the value of x in the image which is brightest if the cylinder is pure Lambertian.

First let's find the normal at the point x in the x - z plane:

$$x^2 + (z - 2)^2 = 1^2$$

$$2x dx + 2(z - 2) dz = 0, \text{ so } \frac{dz}{dx} = \frac{-x}{z - 2}$$

So the surface tangent in the x-z plane is $\begin{bmatrix} -x/(z-2) \\ 1 \end{bmatrix}$ and normal is $\begin{bmatrix} 1 \\ +x/(z-2) \end{bmatrix}$. Now

the vector back to the light source is $\begin{bmatrix} +1 \\ -1 \end{bmatrix}$ so to get them parallel, need $x = -(z - 2)$.

Plugging back into the first equation, we get $x = 1/\sqrt{2} = \sqrt{2}/2 = 0.707$.

Note: here's a quick way to get the answer if you don't remember how to compute normals to curves in general. A unit circle centered at the origin would have a normal of 45° at the point x shown in the diagram below. Clearly, $z=x$. So, since $x^2+z^2=1^2$, the value for x must be $1/\sqrt{2}$. Now if you shift this 2 units up the z-axis, x doesn't change, and you have the same geometry as in this problem. So $x=1/\sqrt{2}$.

