COMP 546

Lecture 10

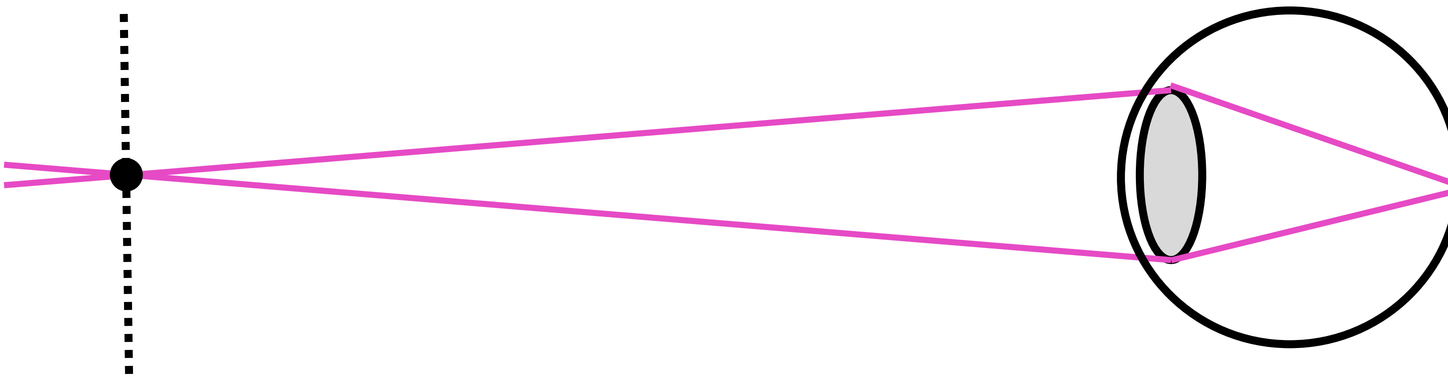
depth from X: defocus blur and binocular disparity

Tues. Feb. 13, 2018

Depth from defocus blur

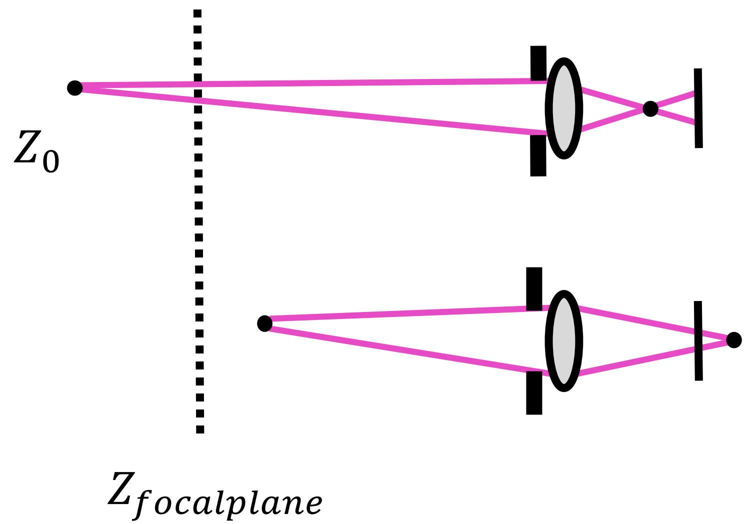
The eye controls f_{lens}, so it "knows" $Z_{focalplane}$.

$$\frac{1}{f_{cornea}} + \frac{1}{f_{lens}} = \frac{1}{Z_{focalplane}} + \frac{1}{Z_{sensor}}$$



$Z_{focalplane}$

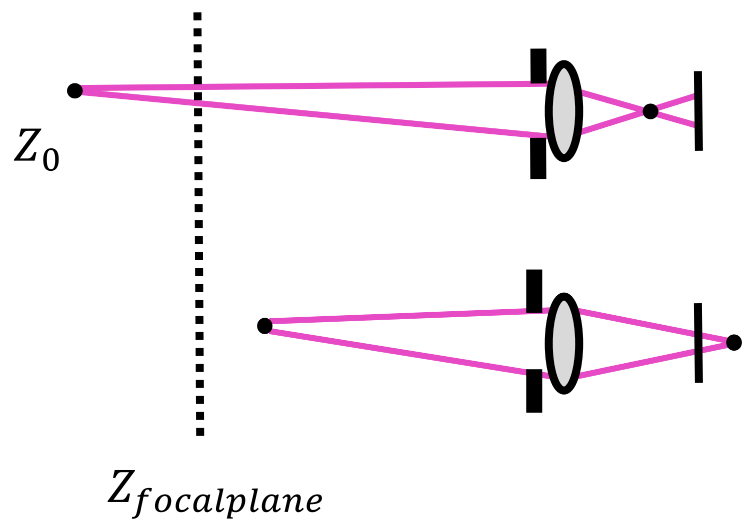
Recall: Depth and Defocus Blur



$$\text{blur width} = \text{aperture} \left| \frac{1}{Z_{focalplane}} - \frac{1}{Z_0} \right|$$

(See Exercise 2 Q 6 & Assignment 1)

Estimating Depth from Defocus Blur



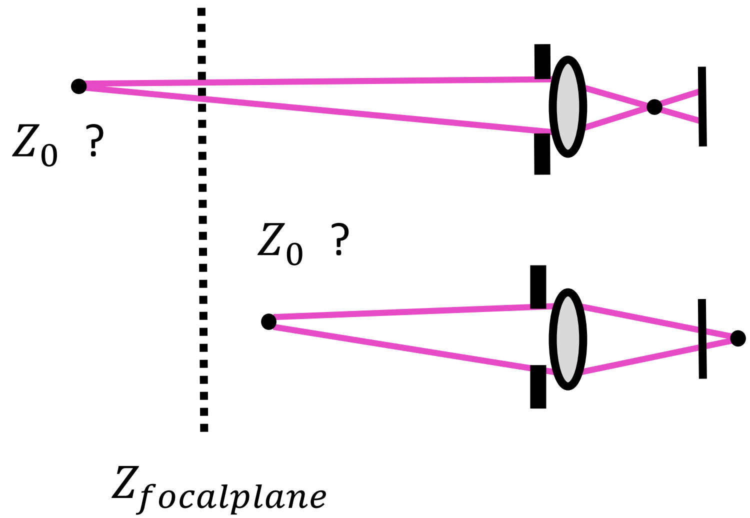
$$\text{blur width} = \text{aperture}\left|\frac{1}{Z_{focalplane}} - \frac{1}{Z_0}\right|$$

2.) measured
(details omitted)

1.) known
(controlled by vision system)

3.) estimated

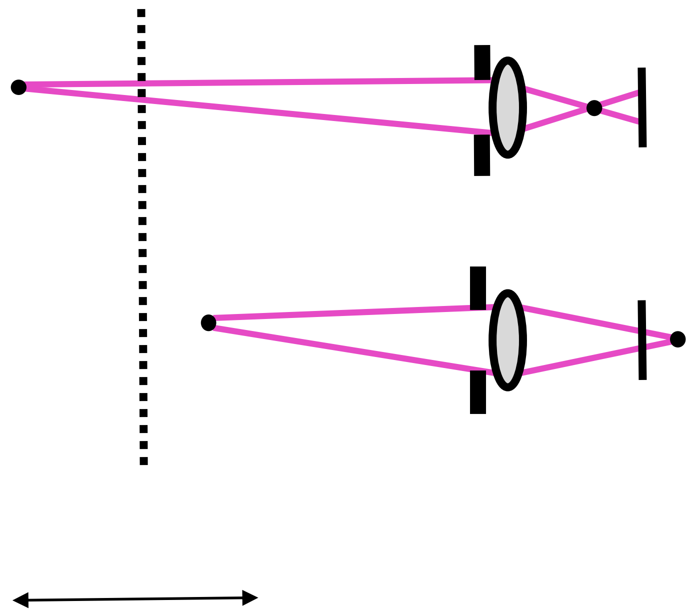
Estimating Depth from Defocus Blur



$$\text{blur width} = \text{aperture} \left| \frac{1}{Z_{focalplane}} - \frac{1}{Z_0} \right|$$

There is a two-fold depth ambiguity.

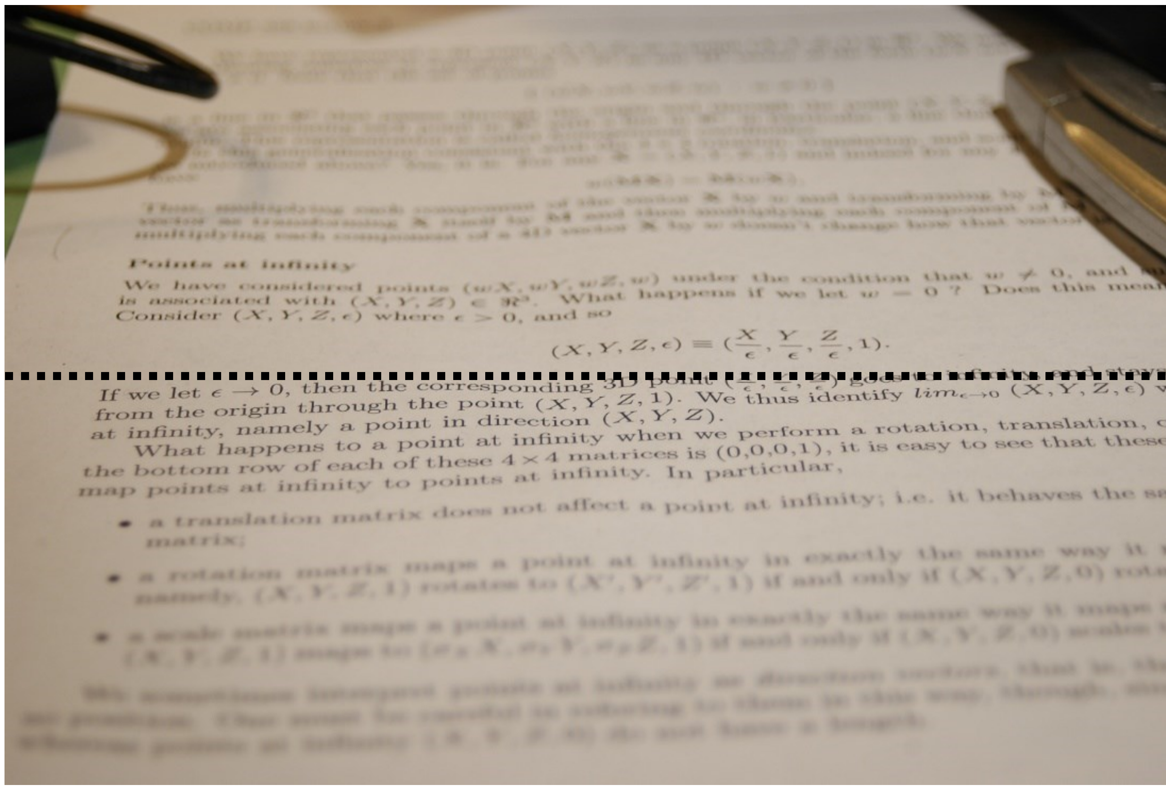
Estimating Depth from Defocus Blur



Varying accommodation resolves the two-fold ambiguity.

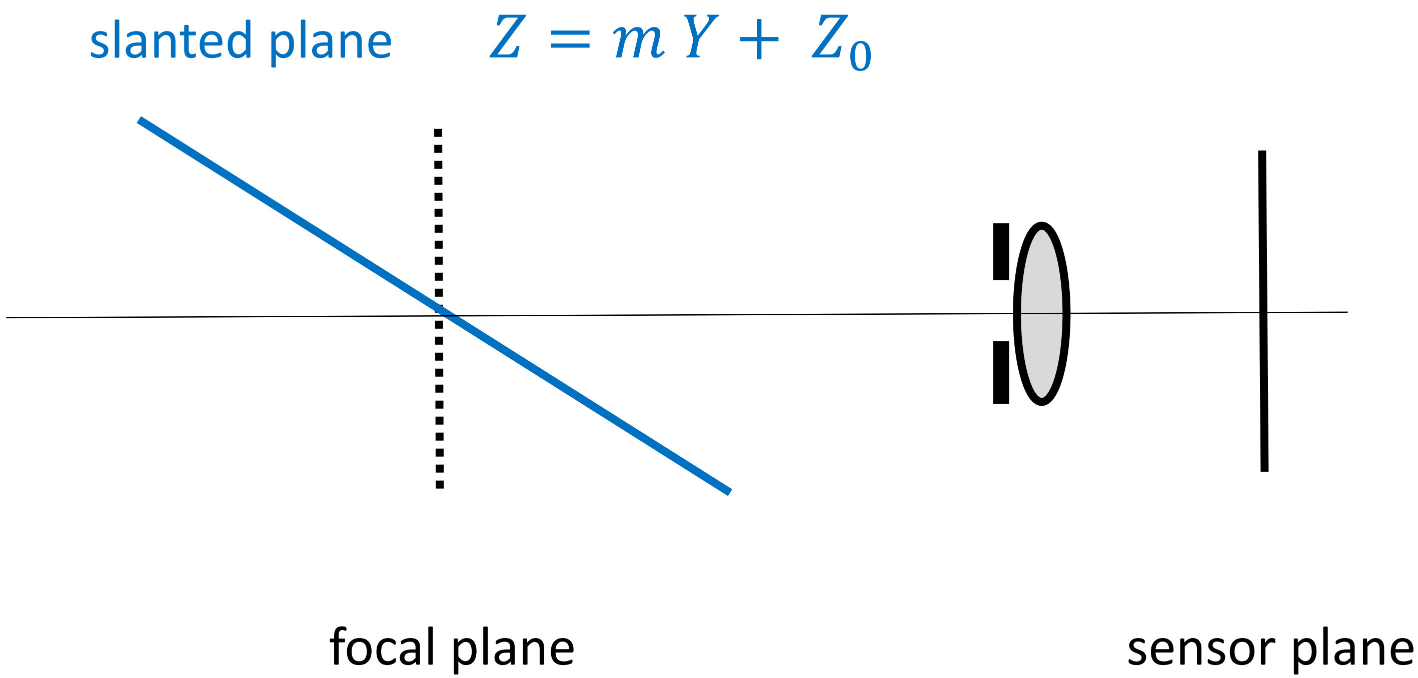
Blur on a slanted plane

focal plane intersection

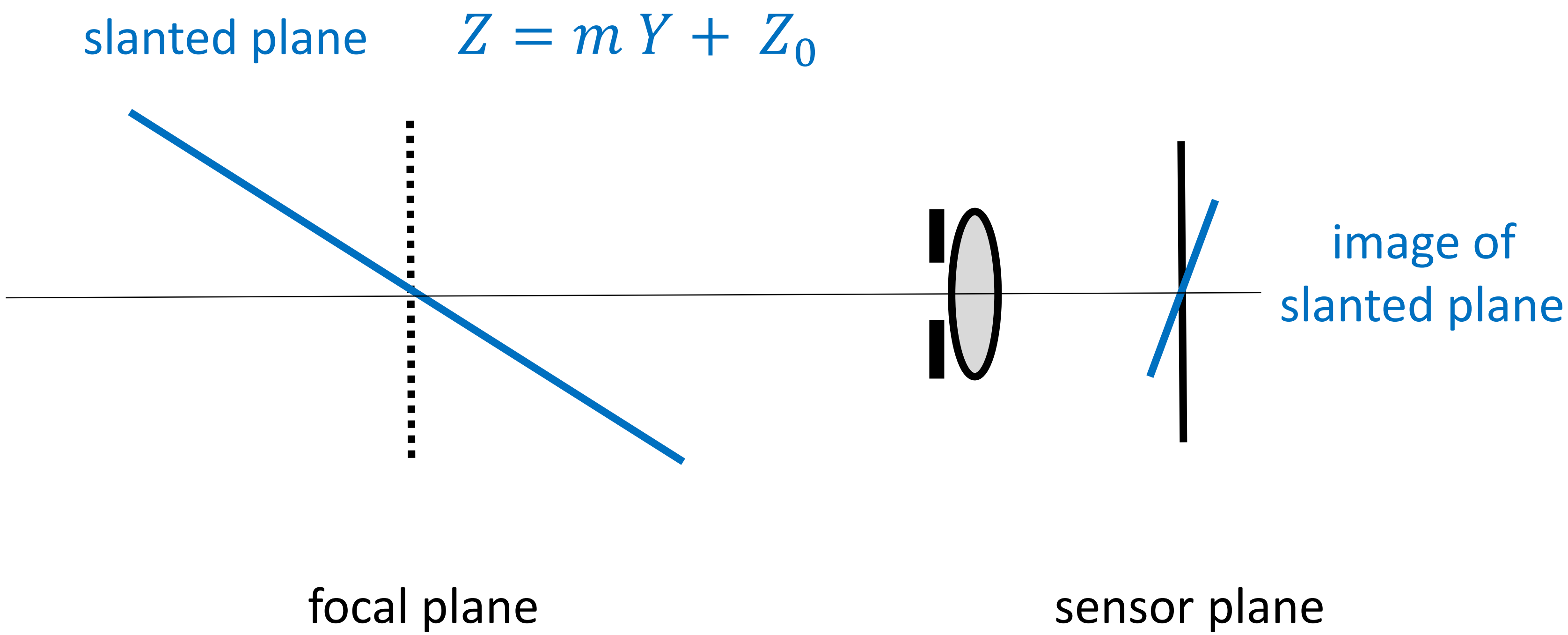


blur gradient

Blur on a slanted plane

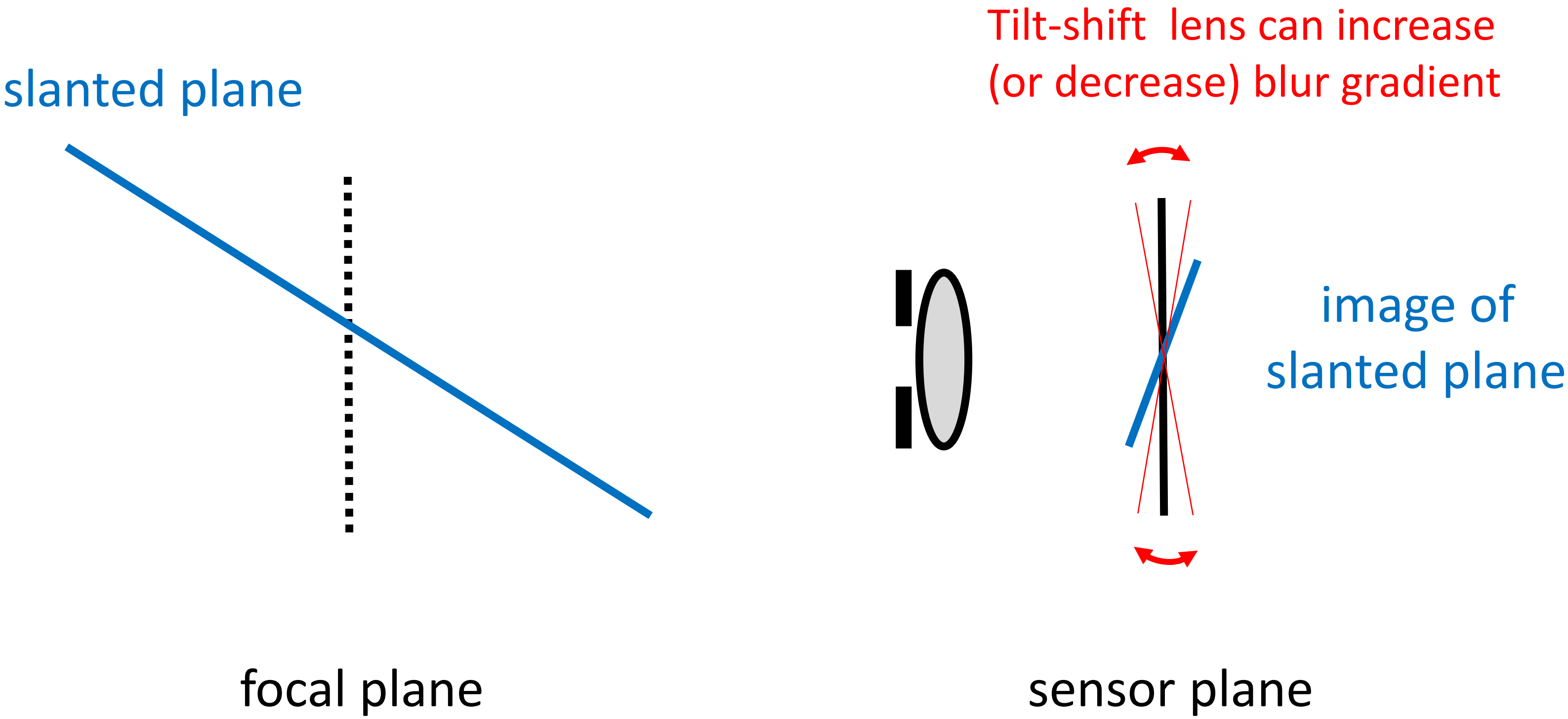


Blur on a slanted plane



See lecture notes: $$\text{blur width (radians)} = A\,\frac{m}{Z_0}\left|\frac{y}{f}\right|$$

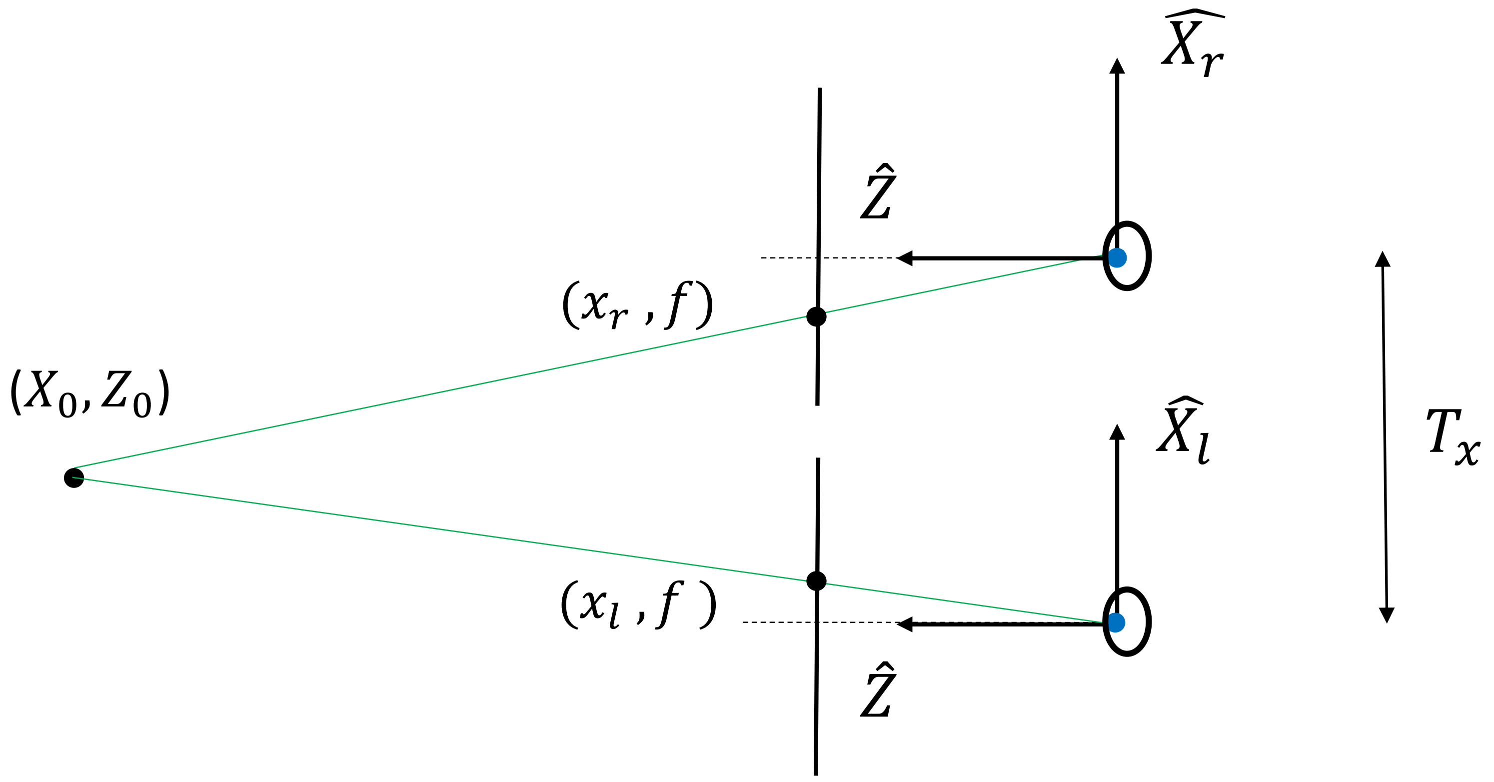
ASIDE: tricks with a tilt-shift lens in photography




9.68

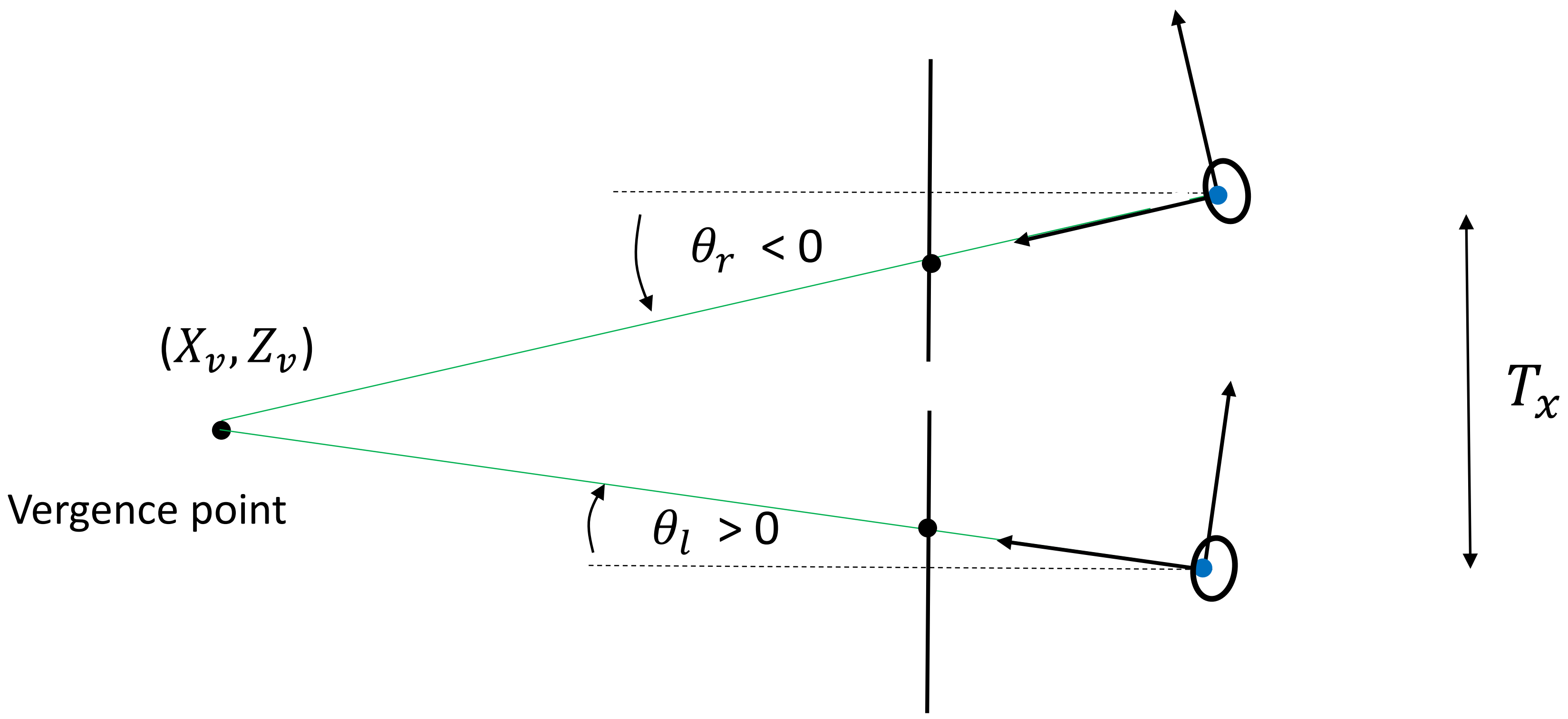
We next examine how defocus blur is related to binocular disparity.

Recall: Binocular disparity and depth

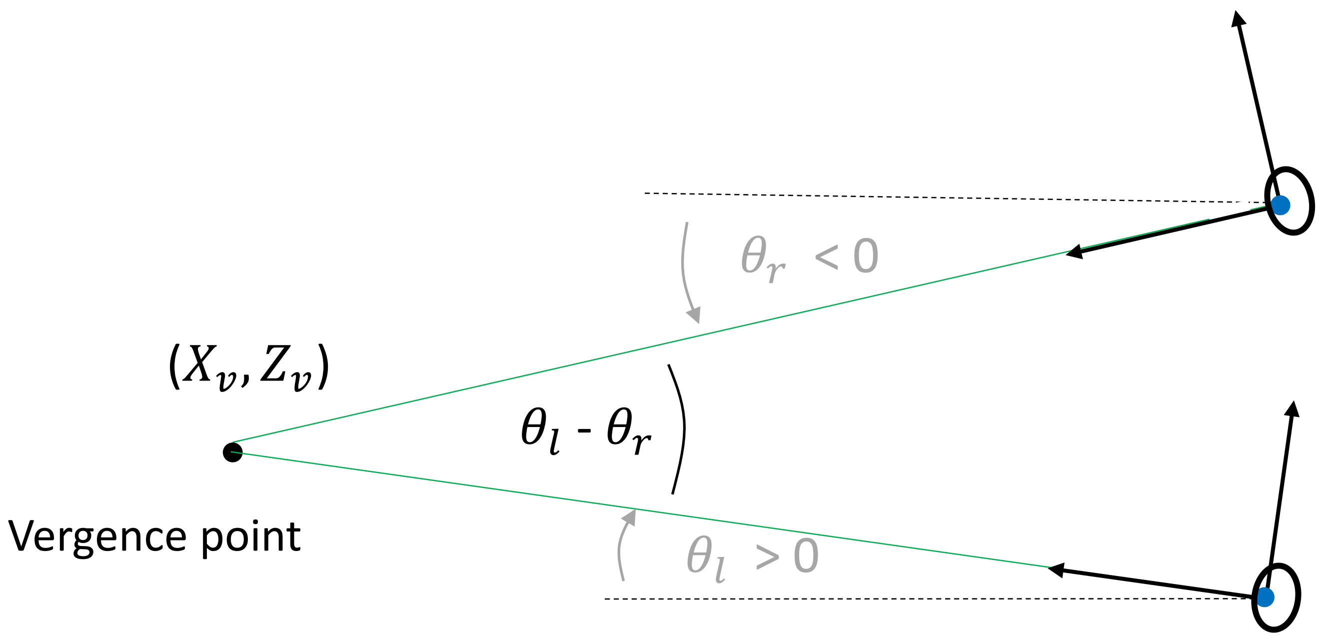


$$\text{disparity} \equiv \frac{x_l}{f} - \frac{x_r}{f} = \frac{T_x}{Z_0}$$

Recall: Binocular vergence

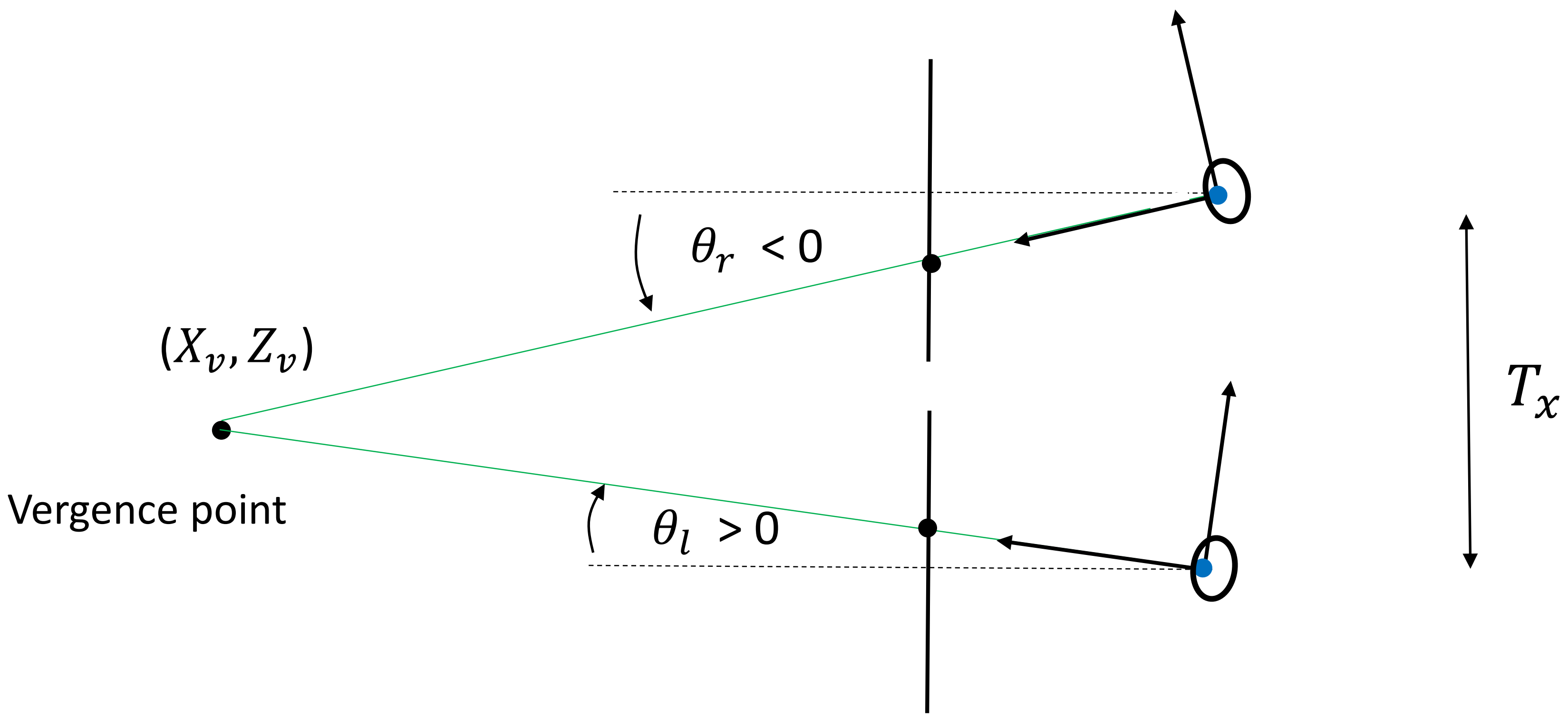


Vergence angle θ_v determines depth



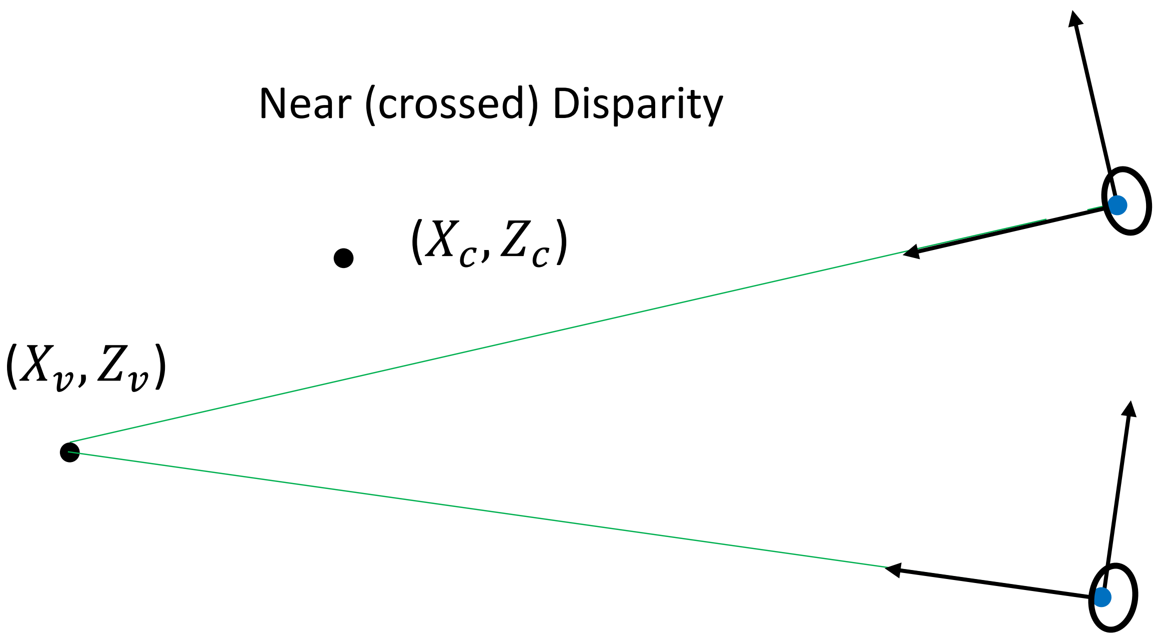
$$\theta_v \equiv \theta_l - \theta_r \approx \frac{x_l}{f} - \frac{x_r}{f} = \frac{T_x}{Z_v}$$

Binocular disparity of vergence point is 0 (obvious).



$$\left(\frac{x_l}{f} - \theta_l\right) - \left(\frac{x_r}{f} - \theta_r\right) = 0 - 0 = 0$$

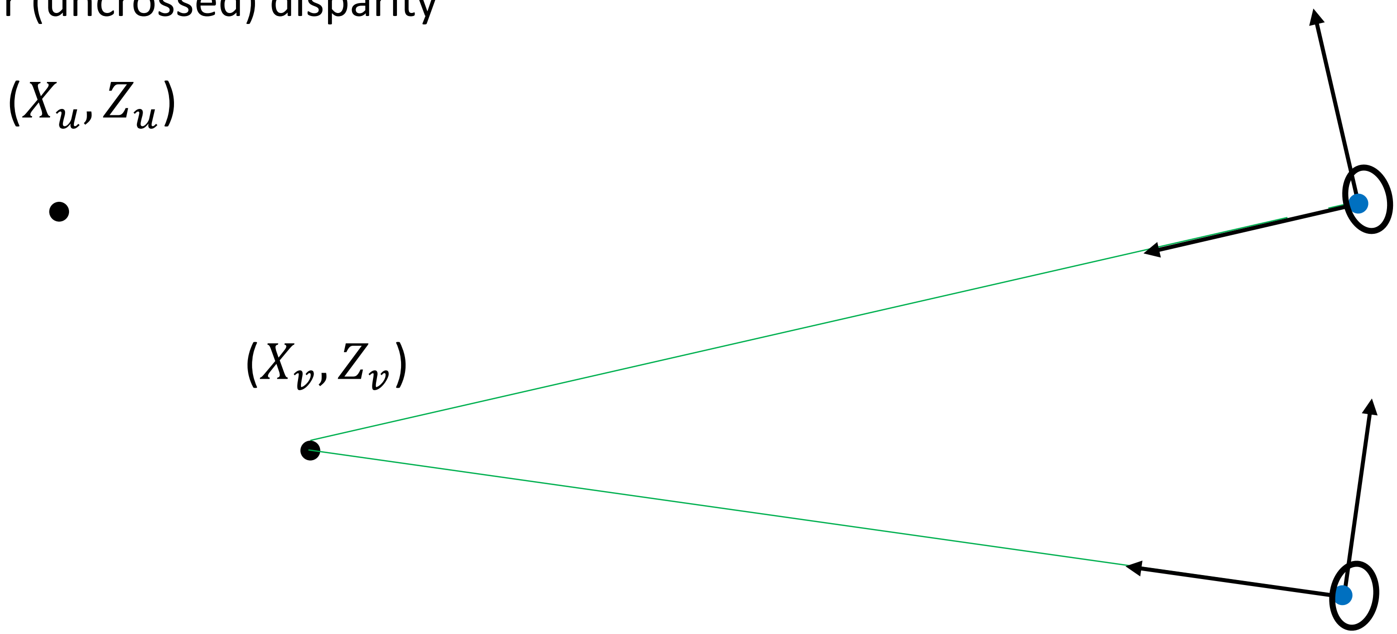
Binocular disparity depends on distance (diopters) from vergence depth.



$$disparity = T_x\left(\frac{1}{Z_c} - \frac{1}{Z_v}\right) > 0$$

Binocular disparity depends on distance (diopters) from vergence depth.

Far (uncrossed) disparity



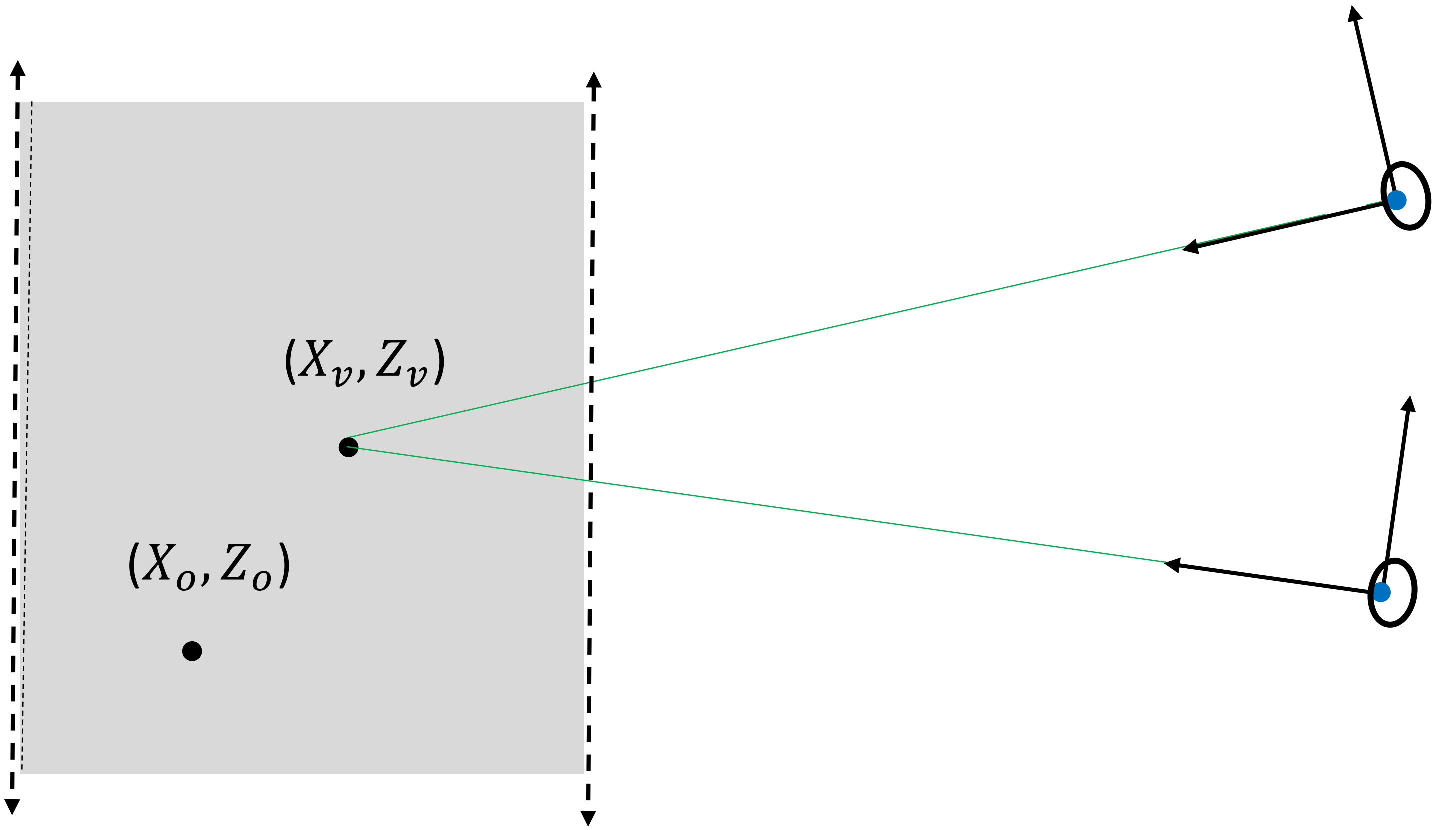
$$disparity = T_x\left(\frac{1}{Z_u} - \frac{1}{Z_v}\right) < 0$$

Binocular Fusion ("Cyclopean Vision")

If disparity is *sufficiently* small, then we fuse the left and right eye images.

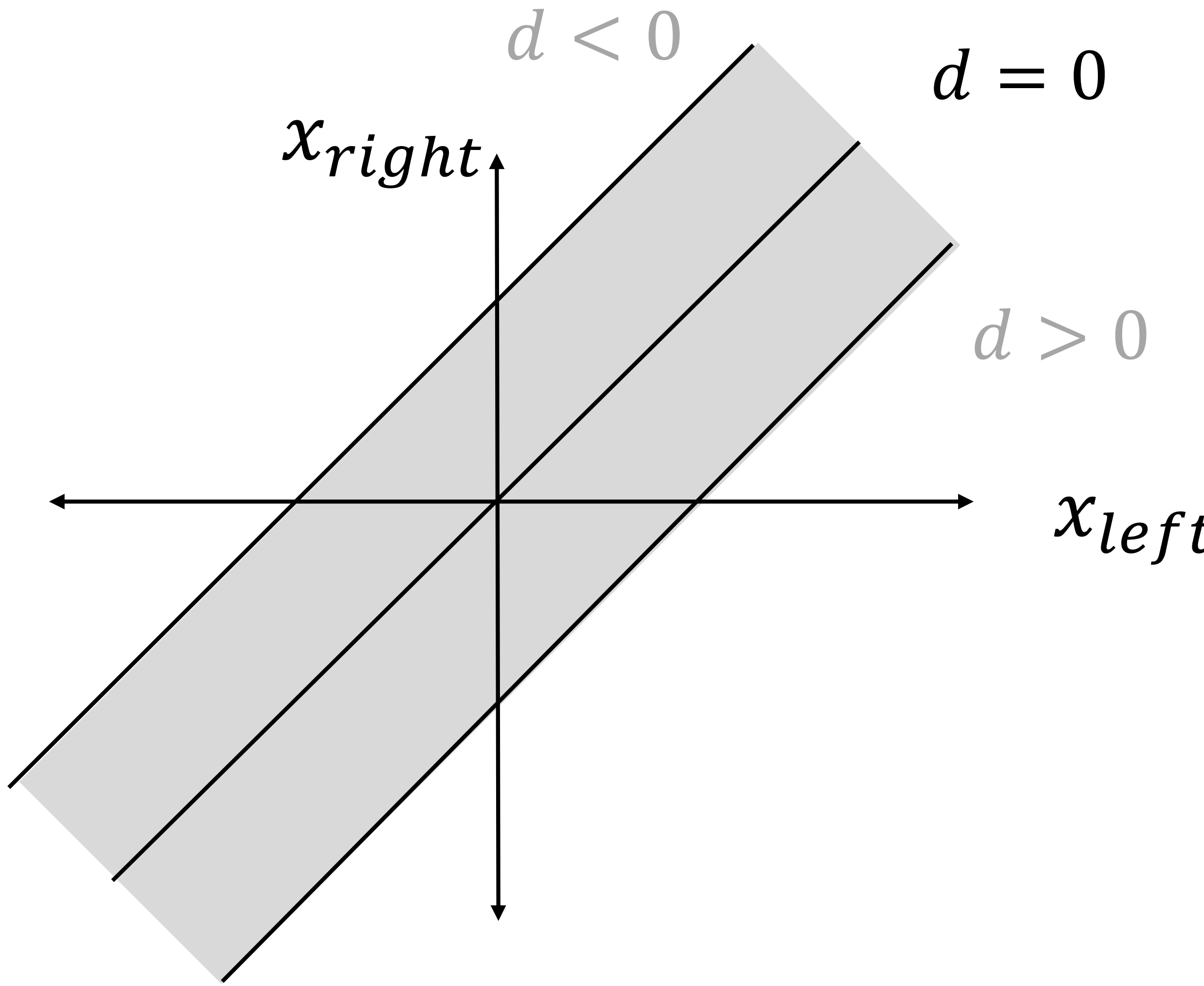
Otherwise, we perceive two images ("diplopia").

Panum's fusional area



$$\text{disparity} \approx T_x \left| \frac{1}{Z_o} - \frac{1}{Z_v} \right| < d_{max}$$

Panum's fusional area in disparity space



Binocular disparity and blur

$$\text{disparity} = \text{IOD} \left(\frac{1}{\text{object dist}} - \frac{1}{\text{vergence dist}} \right)$$

interocular distance or T_X

$$\text{blur width} = \text{aperture} \left| \frac{1}{\text{object dist}} - \frac{1}{\text{focal dist}} \right|$$

Binocular disparity and blur

$$\text{disparity} = \text{IOD} \left(\frac{1}{\text{object dist}} - \frac{1}{\text{vergence dist}} \right)$$

$$\text{blur width} = \text{aperture} \left| \frac{1}{\text{object dist}} - \frac{1}{\text{focal dist}} \right|$$

If vergence distance = focal distance then

$$\frac{|\text{ disparity }|}{\text{blur}} = \frac{\text{IOD}}{\text{aperture}} \approx 10$$

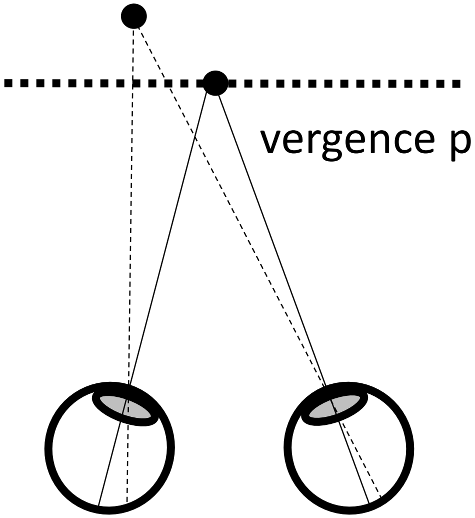
Vergence and accommodation systems are coupled.

We verge at the same depth as we focus
(even if one eye is closed)
and vice-versa.

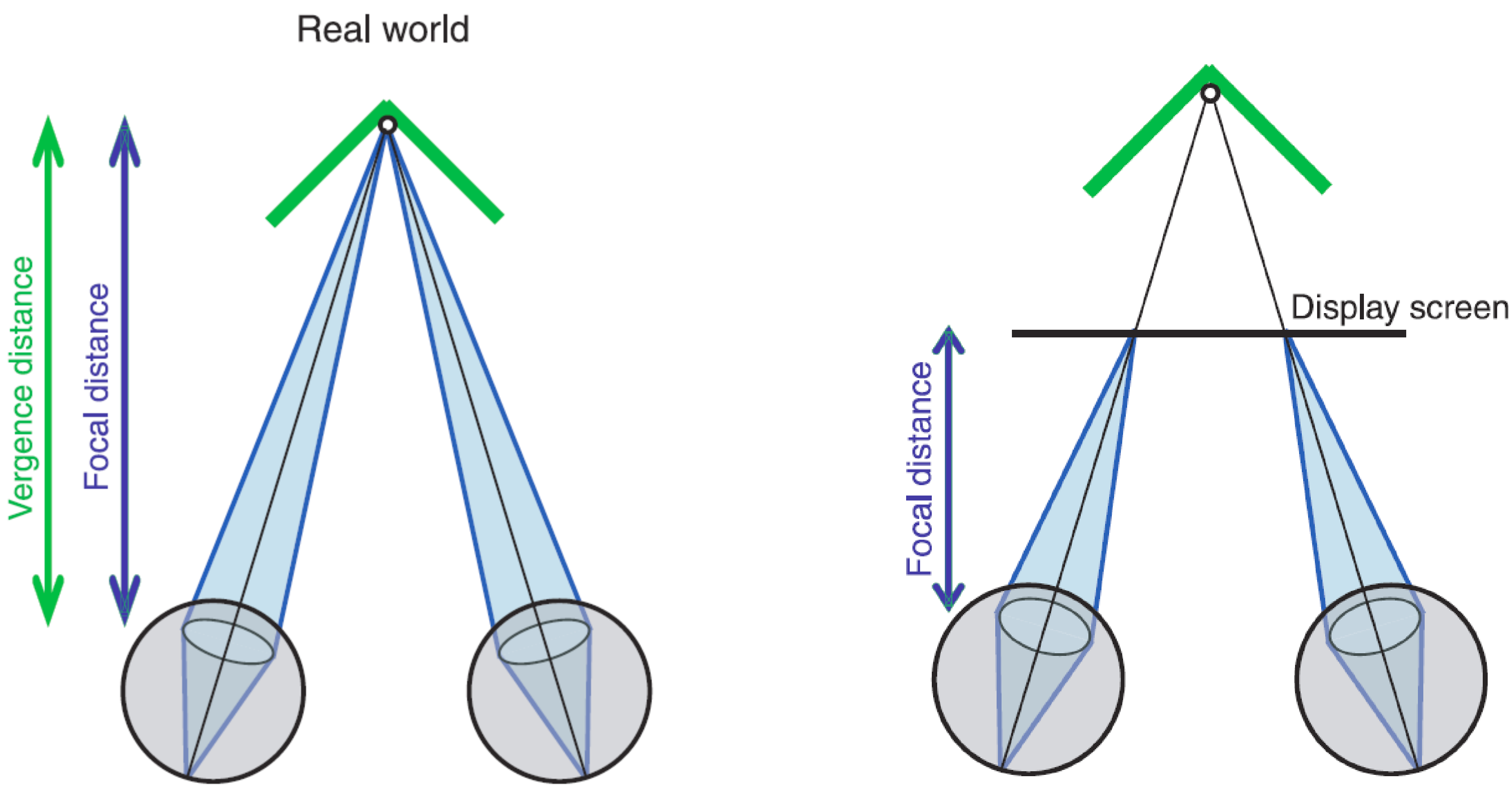
Monocular

Binocular

Limitations on 3D cinema



3D stereo displays can create accommodation-vergence conflict



[Hoffman et al 2008]

How to study binocular stereo vision ?

Neuroscience

- Show cats or monkeys different images to the left and right eyes and measure brain activity.

Computational modelling

- Write a computer program that finds matching points in left and right images, in a biologically plausible way

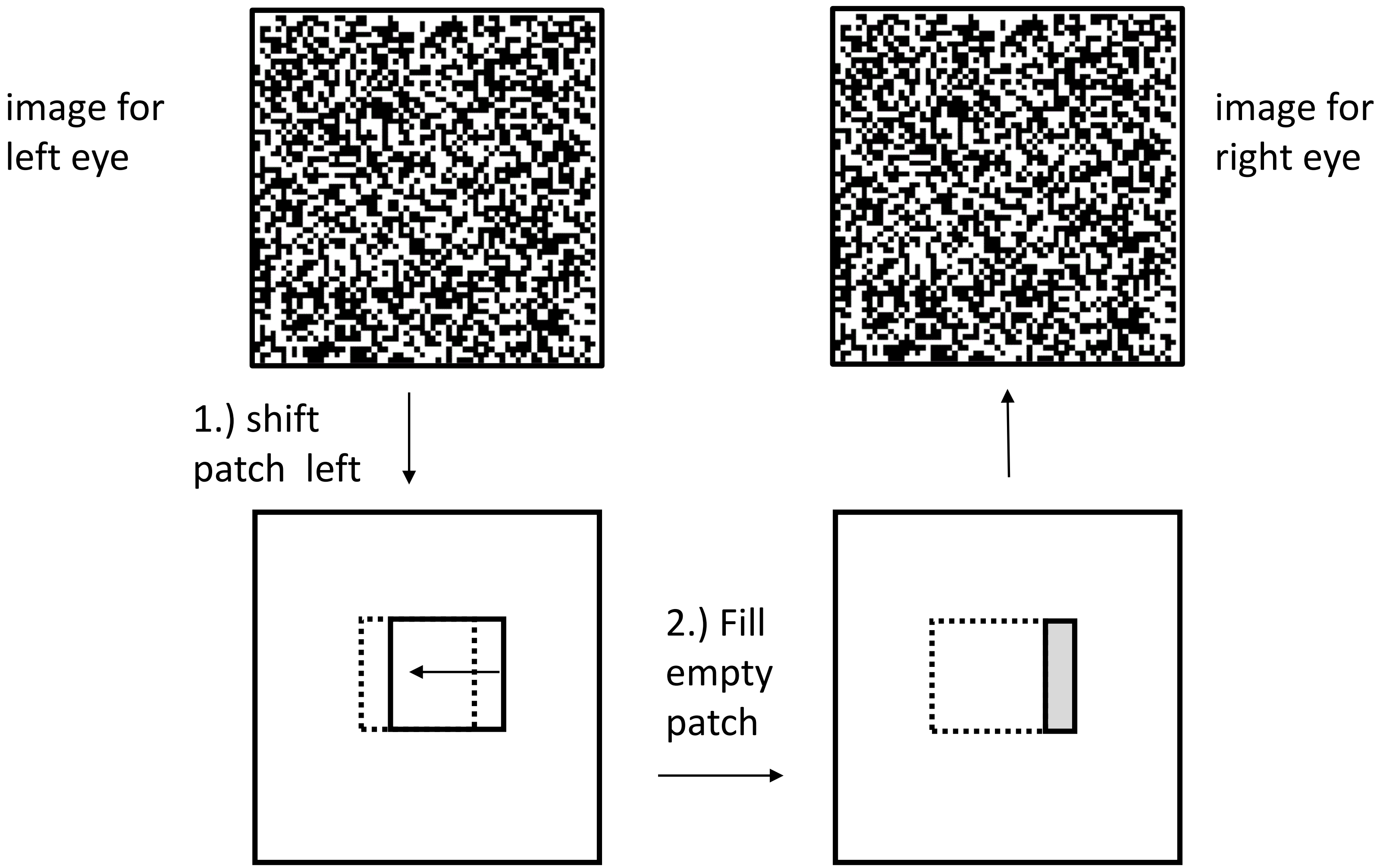
Psychology

- Show people different images to the left and right eyes and measure how well the people judge depth.

Random Dot Stereogram

Bela Julesz, "Binocular depth perception *without familiarity cues*" *Science* 1964.

How to make a random dot stereogram?



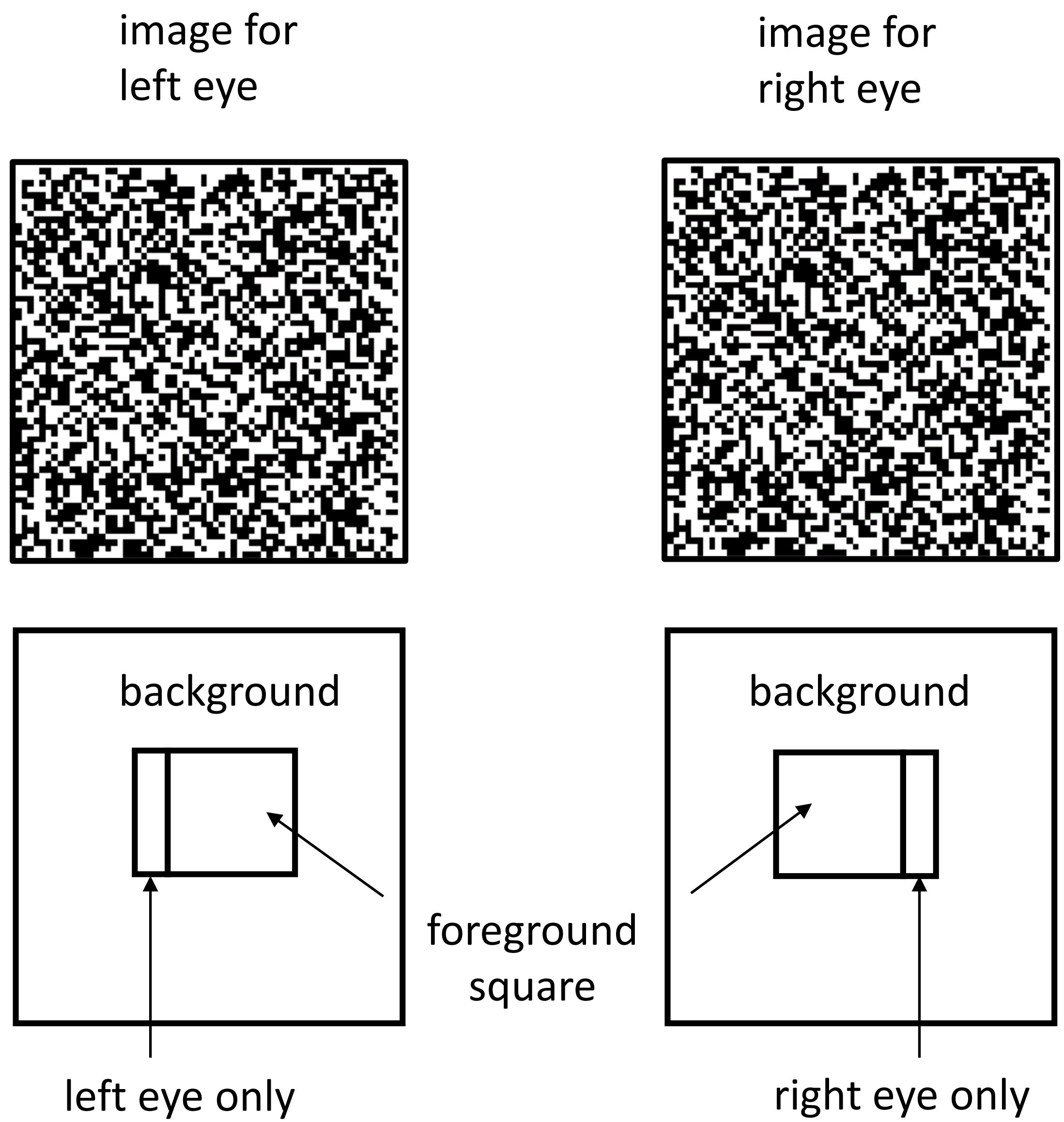


image for
left eye
image for
right eye
background
background
foreground
square
left eye only
right eye only

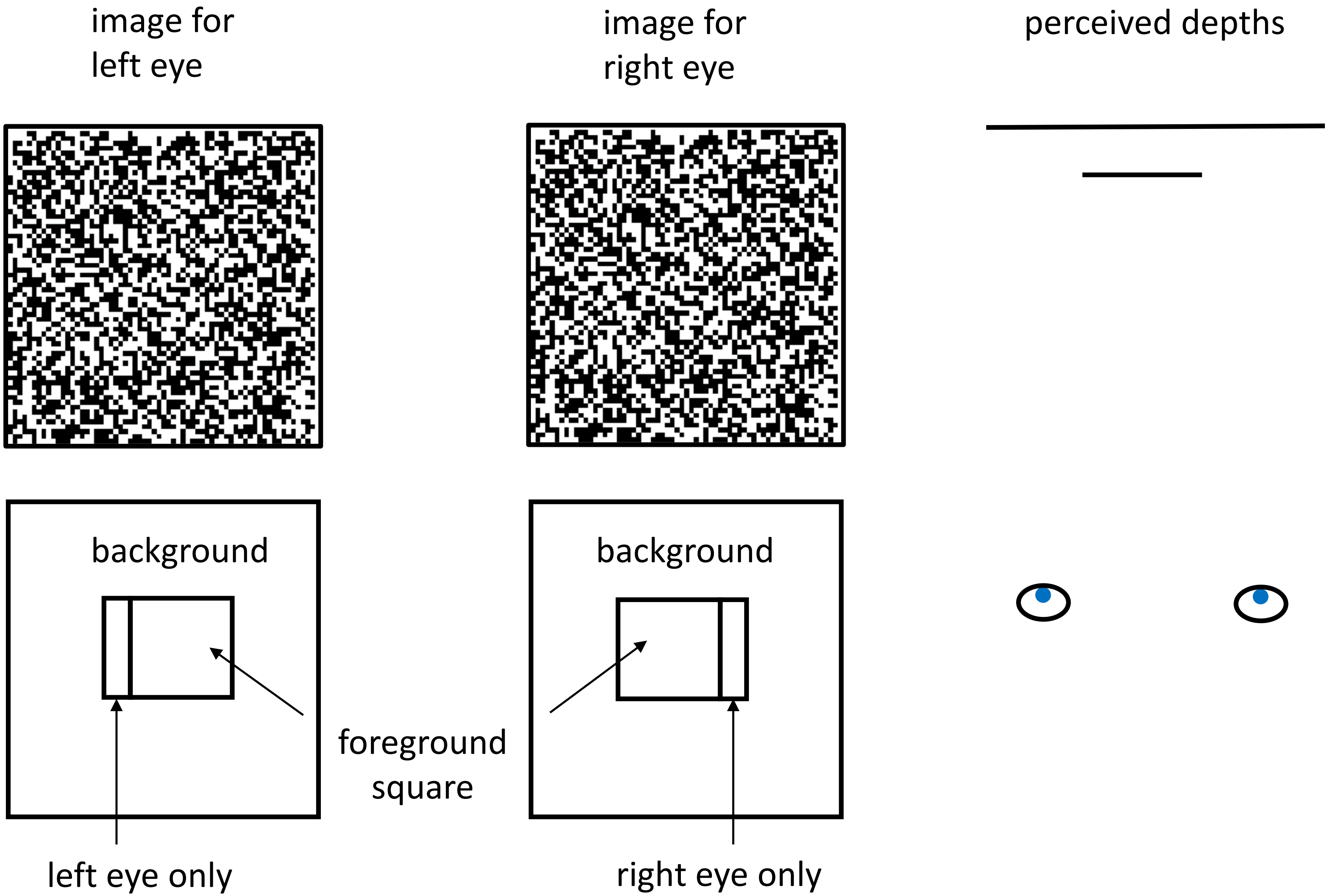
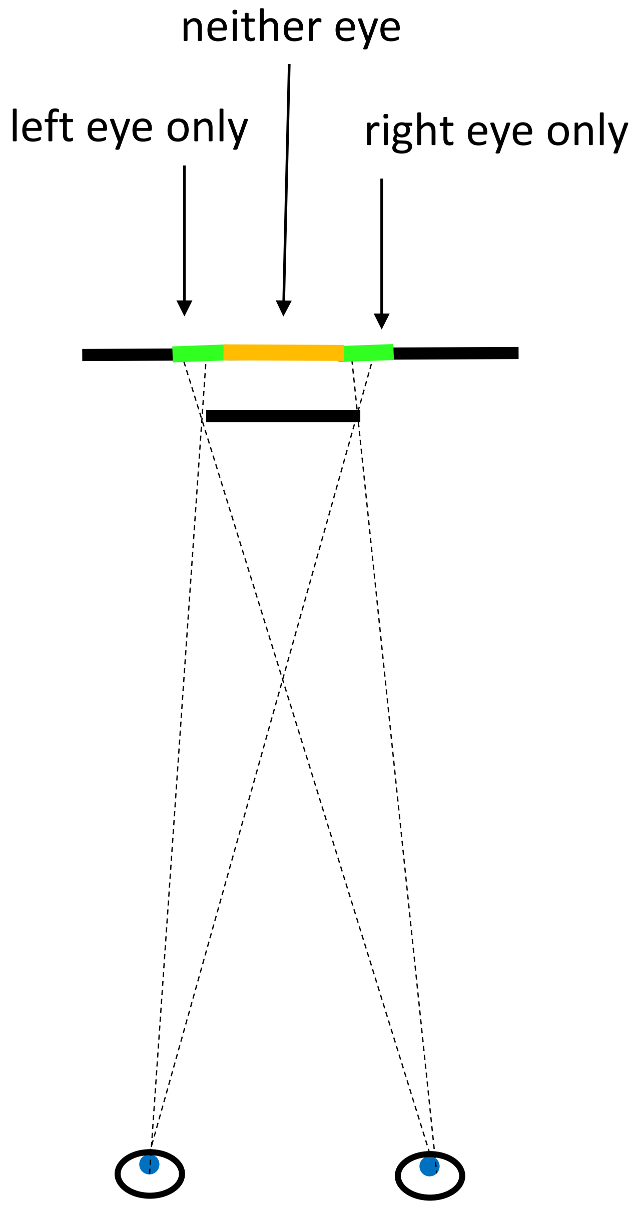
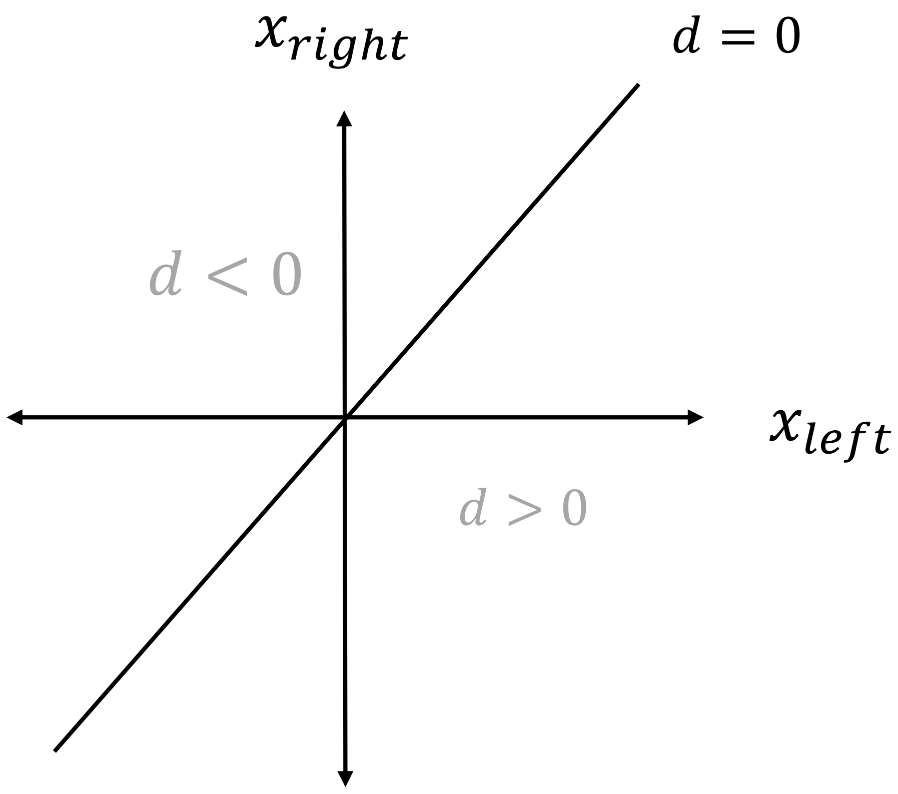


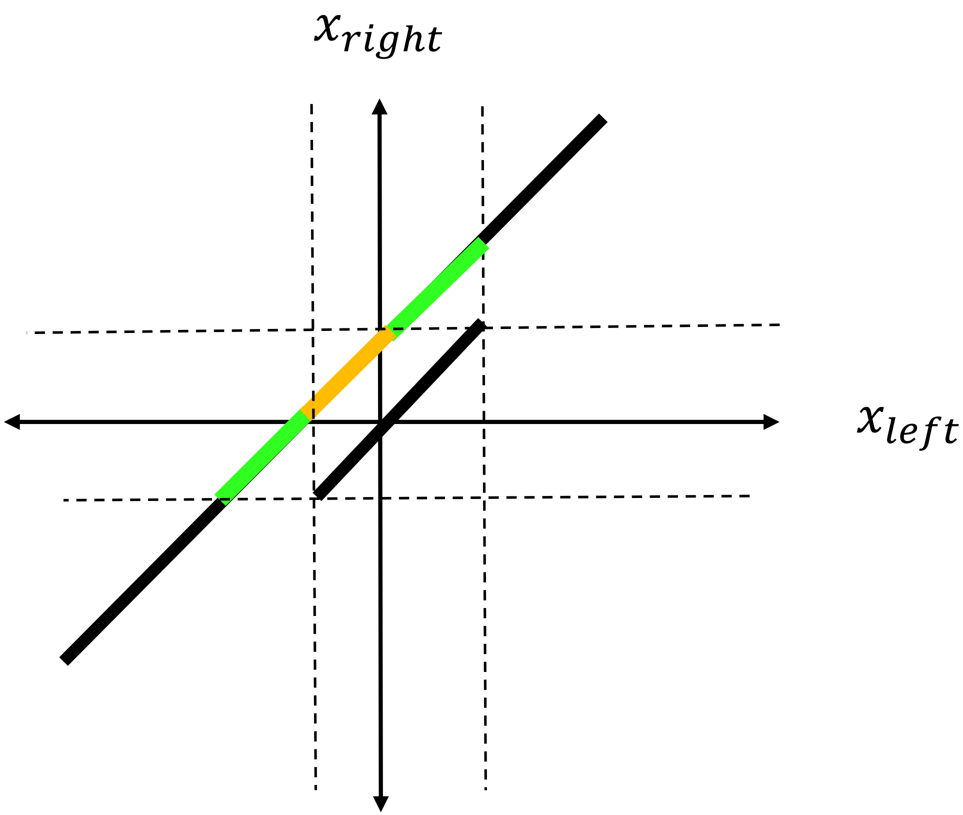
image for
left eye
image for
right eye
perceived depths
background
background
foreground
square
left eye only
right eye only

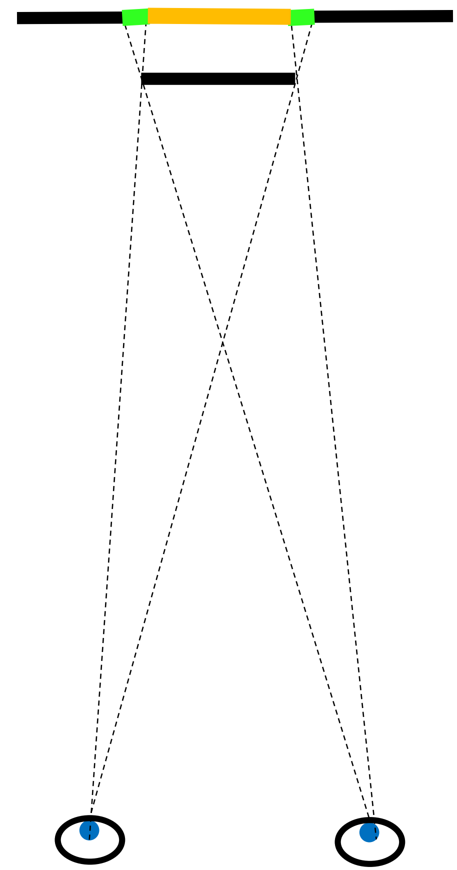

neither eye
left eye only
right eye only

Disparity Space



Disparity Space





Q: where are the eyes verging?