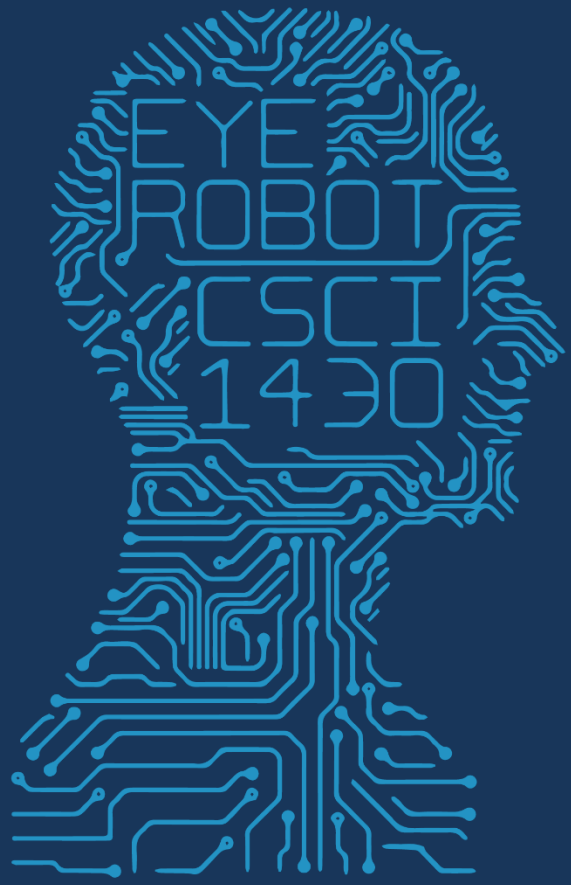
1950

Future Vision



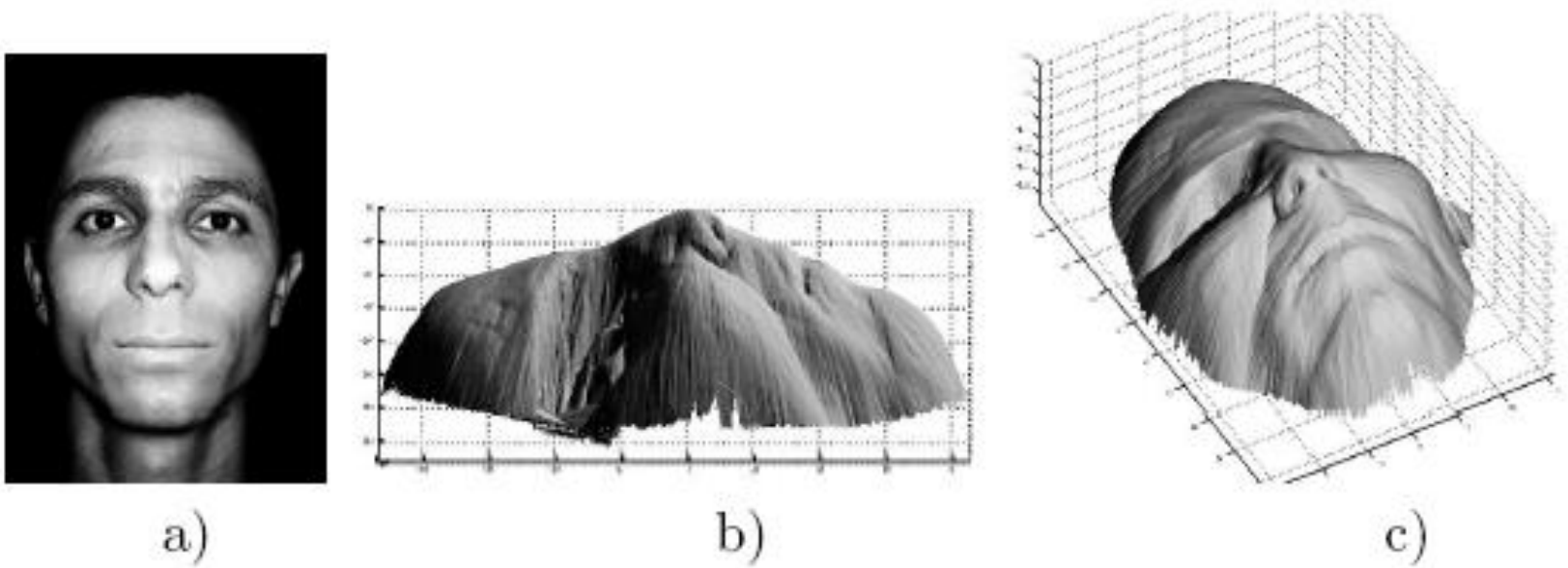
2017 MWF 1pm 368

Computer Vision

Think-Pair-Share

What visual or physiological cues help us to perceive 3D shape and depth?

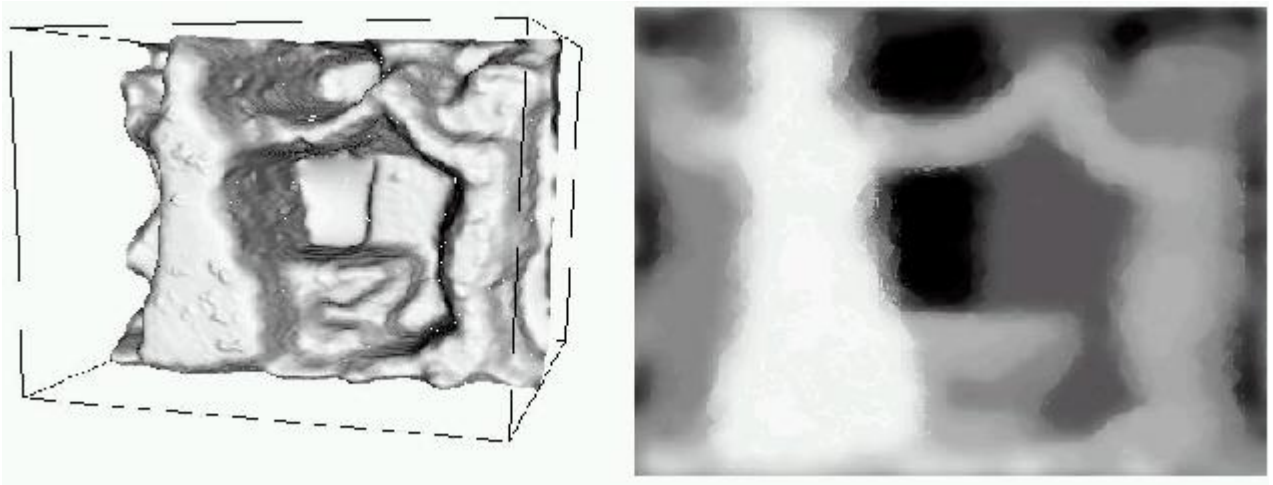
Shading



[Figure from Prados & Faugeras 2006]

Focus/defocus

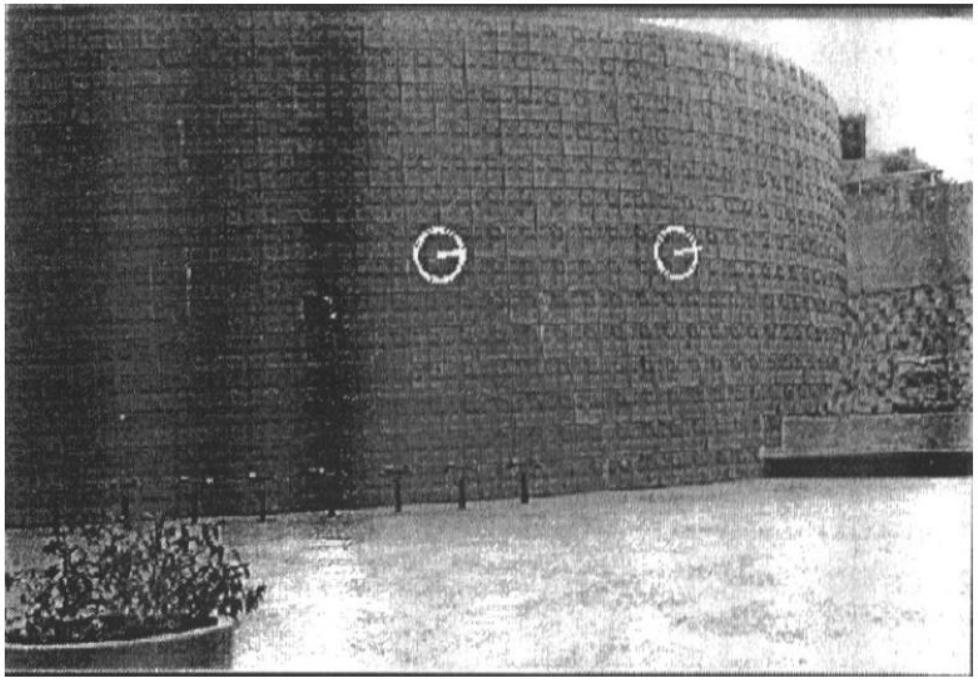
Images from same point of view, different camera parameters

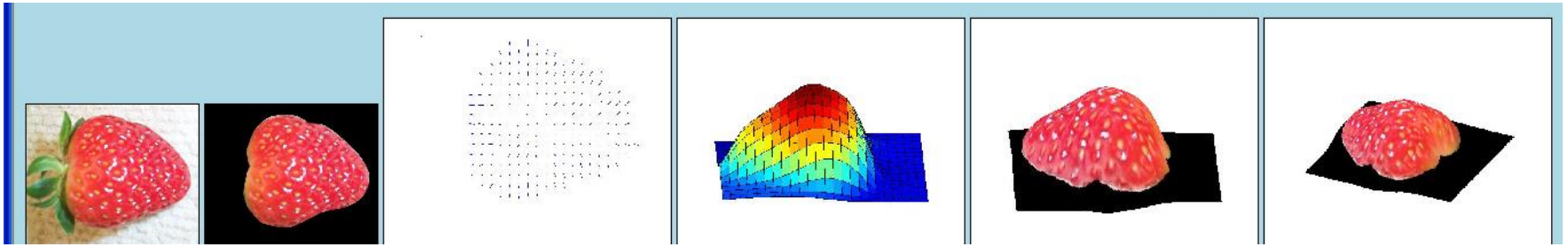


3d shape / depth estimates

[figs from H. Jin and P. Favaro, 2002]

Texture





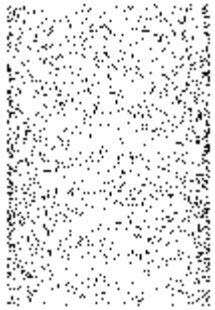
[From A.M. Loh. The recovery of 3-D structure using visual texture patterns. PhD thesis]

Perspective effects

Image credit: S. Seitz

Motion



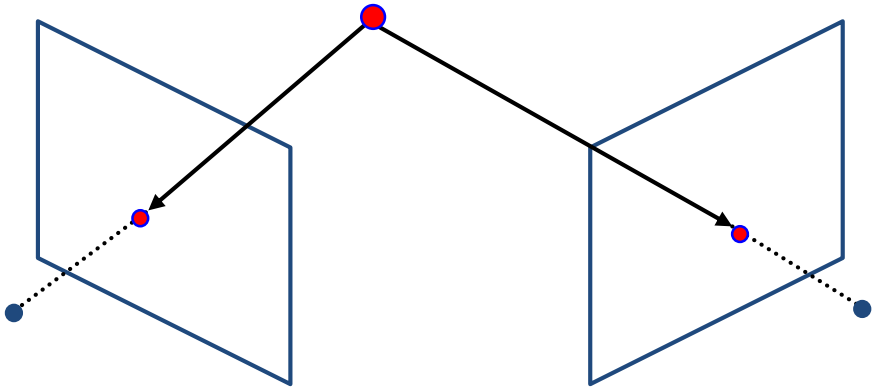
Figures from L. Zhang

http://www.brainconnection.com/teasers/?main=illusion/motion-shape

Occlusion

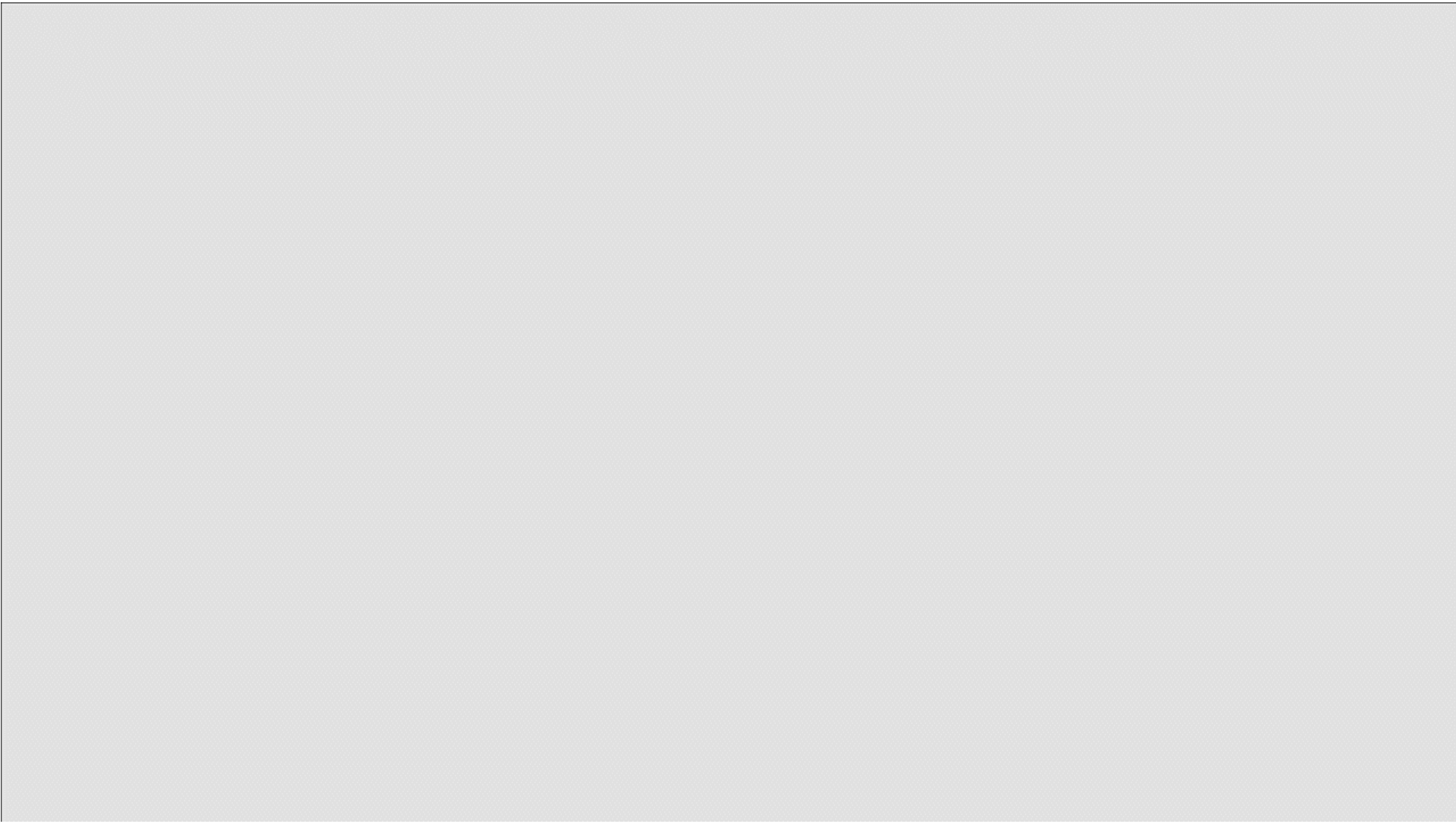
Rene Magritt'e famous painting *Le Blanc-Seing* (literal translation: "The Blank Signature") roughly translates as "free hand" or "free rein".

Stereo



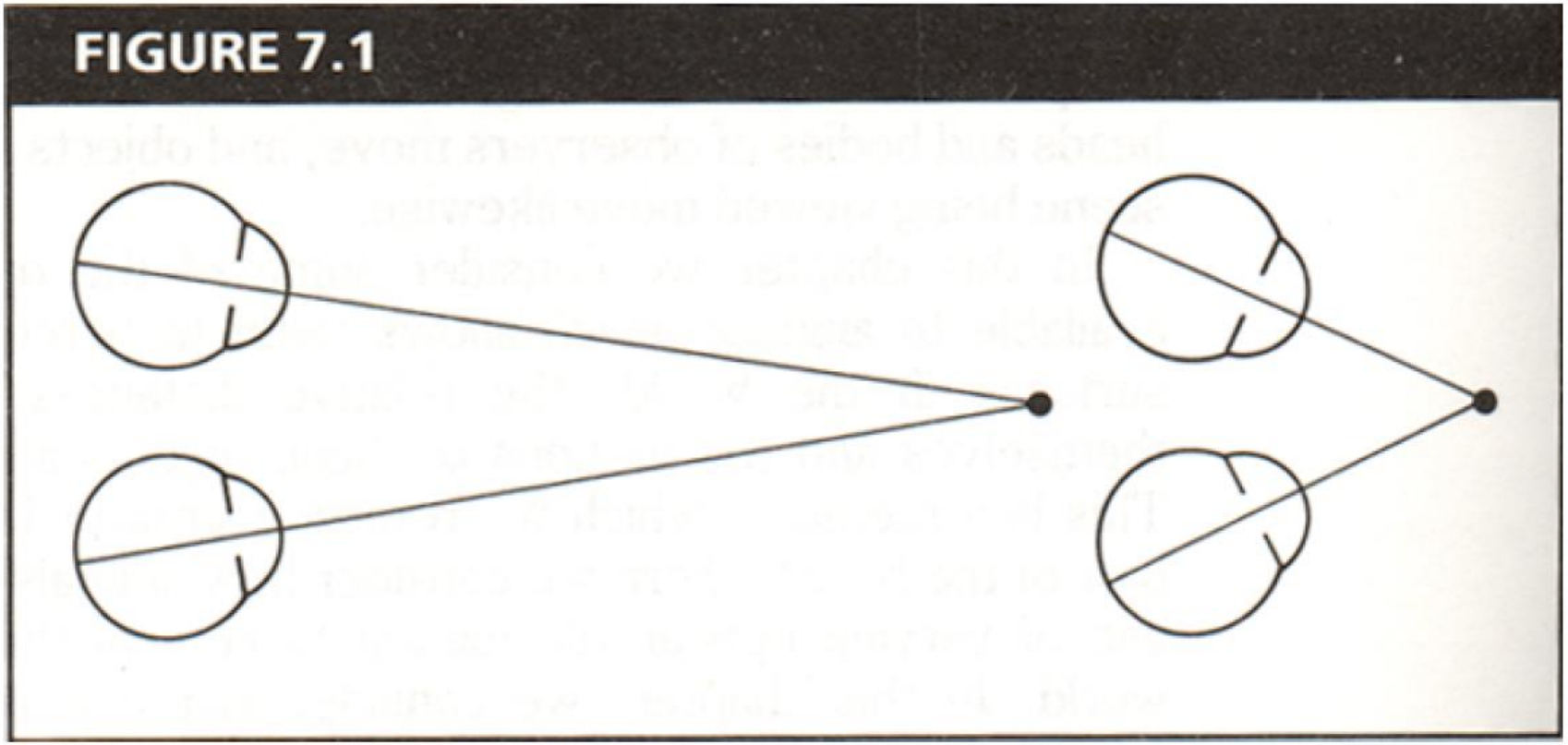
Slides: James Hays and Kristen Grauman

If stereo were critical for depth perception, navigation, recognition, etc., then rabbits would never have evolved.



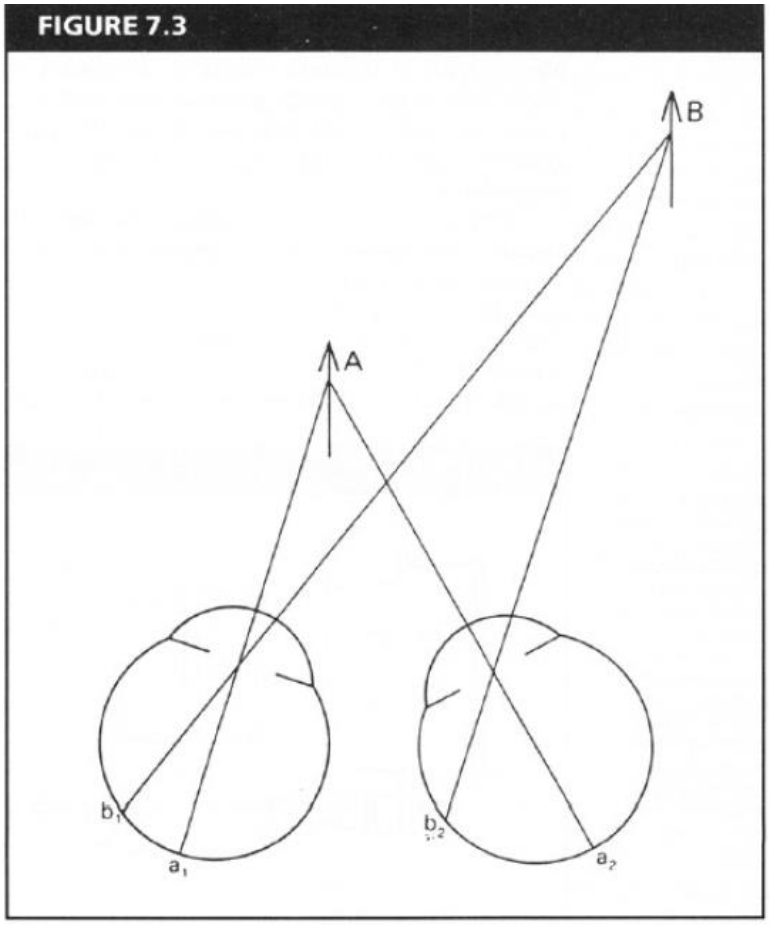
Human stereopsis

Human eyes **fixate** on point in space – rotate so that corresponding images form in centers of fovea.



From Bruce and Green, Visual Perception, Physiology, Psychology and Ecology

Human stereopsis: disparity

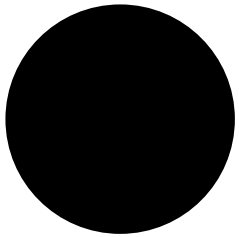


From Bruce and Green, Visual Perception, Physiology, Psychology and Ecology

Disparity occurs when eyes fixate on one object; others appear at different visual angles.

Disparity is distance from b1 to b2 along retina.

Yes, you can be stereoblind.



Random dot stereograms

- Julesz 1960:

  Do we identify local brightness patterns before fusion (monocular process) or after (binocular)?

- Think Pair Share – yes / no? how to test?

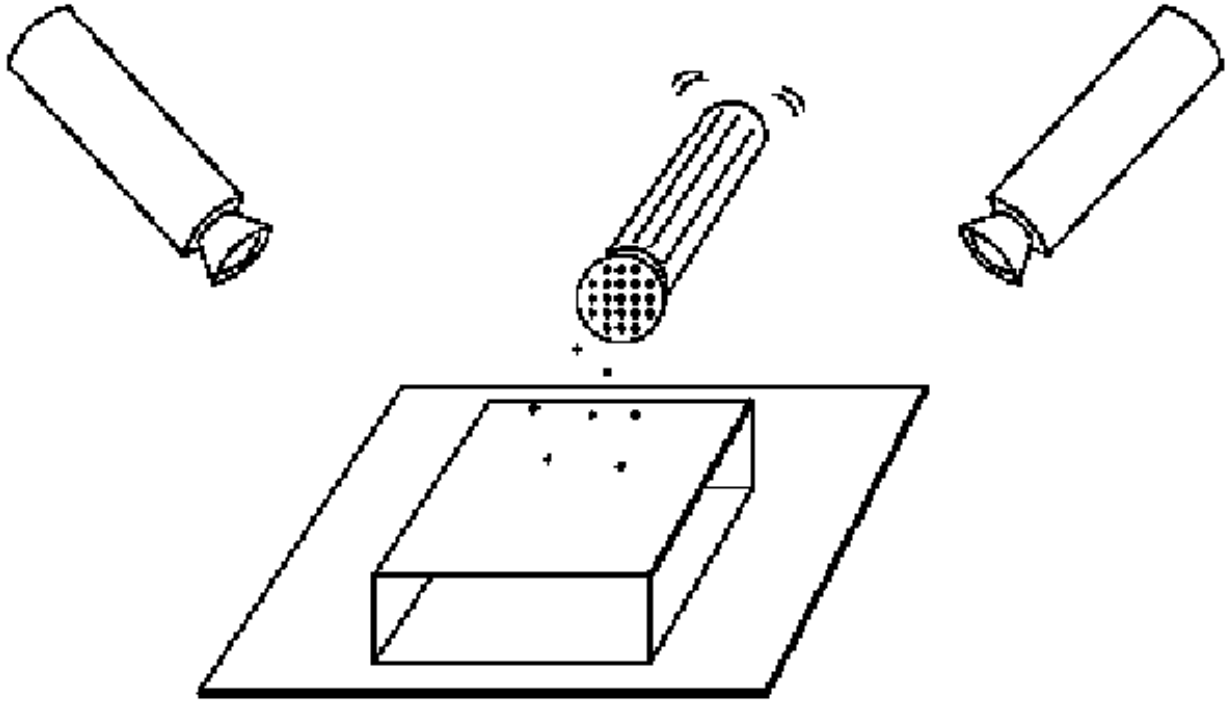
Random dot stereograms

- Julesz 1960:

  Do we identify local brightness patterns before fusion (monocular process) or after (binocular)?

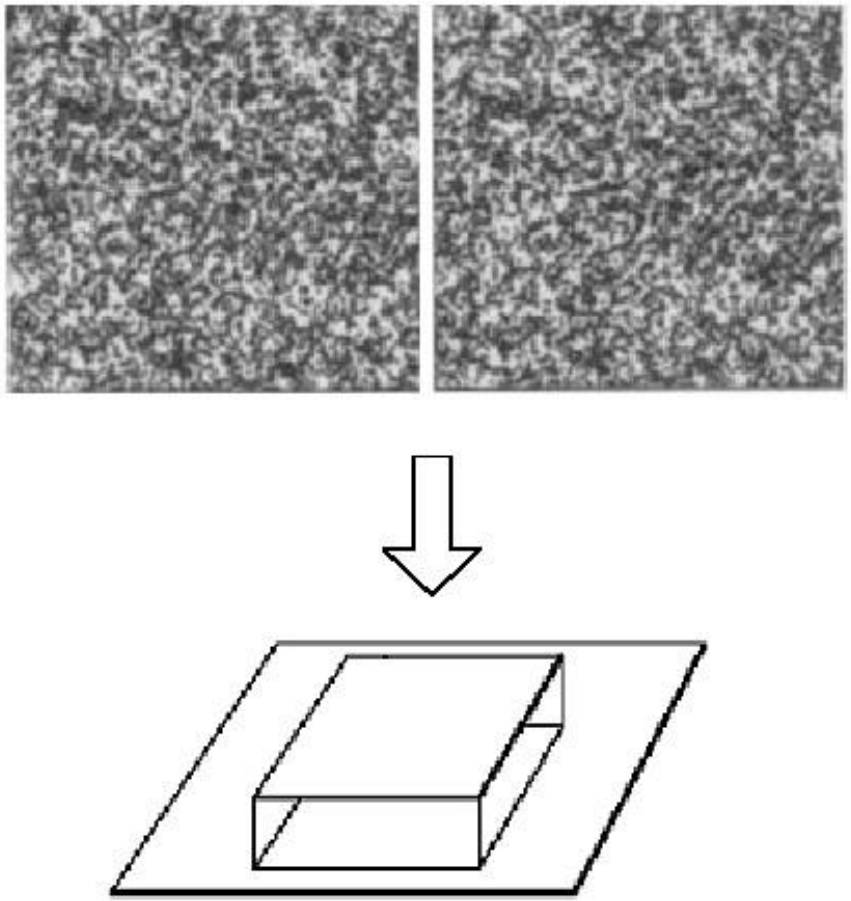
- To test: pair of synthetic images obtained by randomly spraying black dots on white objects

Random dot stereograms



Forsyth & Ponce

Random dot stereograms



1. Create an image of suitable size. Fill it with random dots. Duplicate the image.

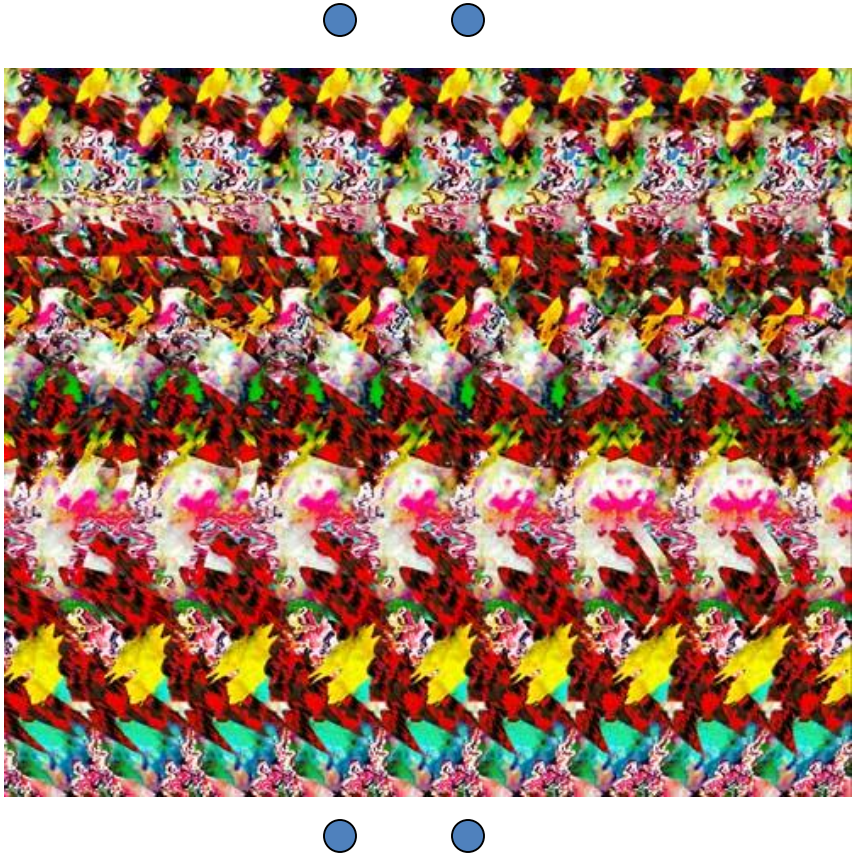
2. Select a region in one image.

3. Shift this region horizontally by a small amount. The stereogram is complete.

Random dot stereograms

- When viewed monocularly, they appear random; when viewed stereoscopically, see 3d structure.
- Human binocular fusion not directly associated with the physical retinas; must involve the central nervous system (V2, for instance).
- Imaginary "*cyclopean retina*" that combines the left and right image stimuli as a single unit.
- High level scene understanding not required for stereo…but, high level scene understanding is arguably *better* than stereo.

Autostereograms – ‘Magic Eye’



Exploit disparity as depth cue using single image.

(Single image random dot stereogram, Single image stereogram)

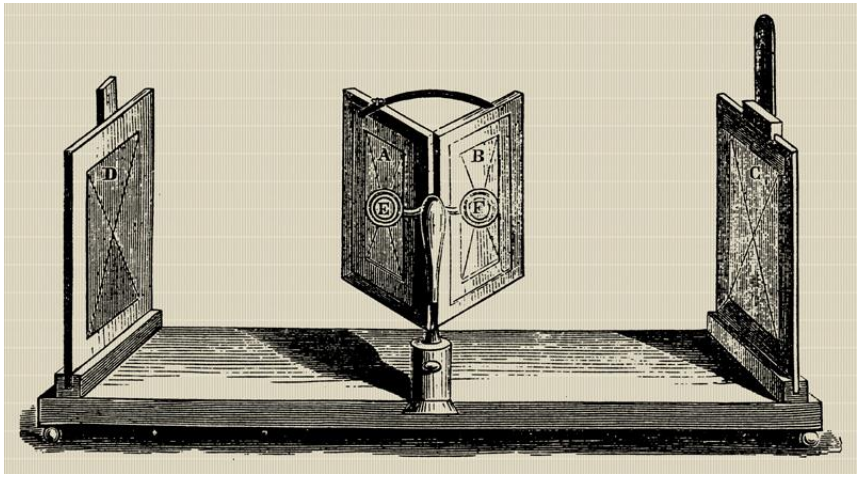
Images from magiceye.com

Autostereograms

Images from magiceye.com

Stereo photography and stereo viewers

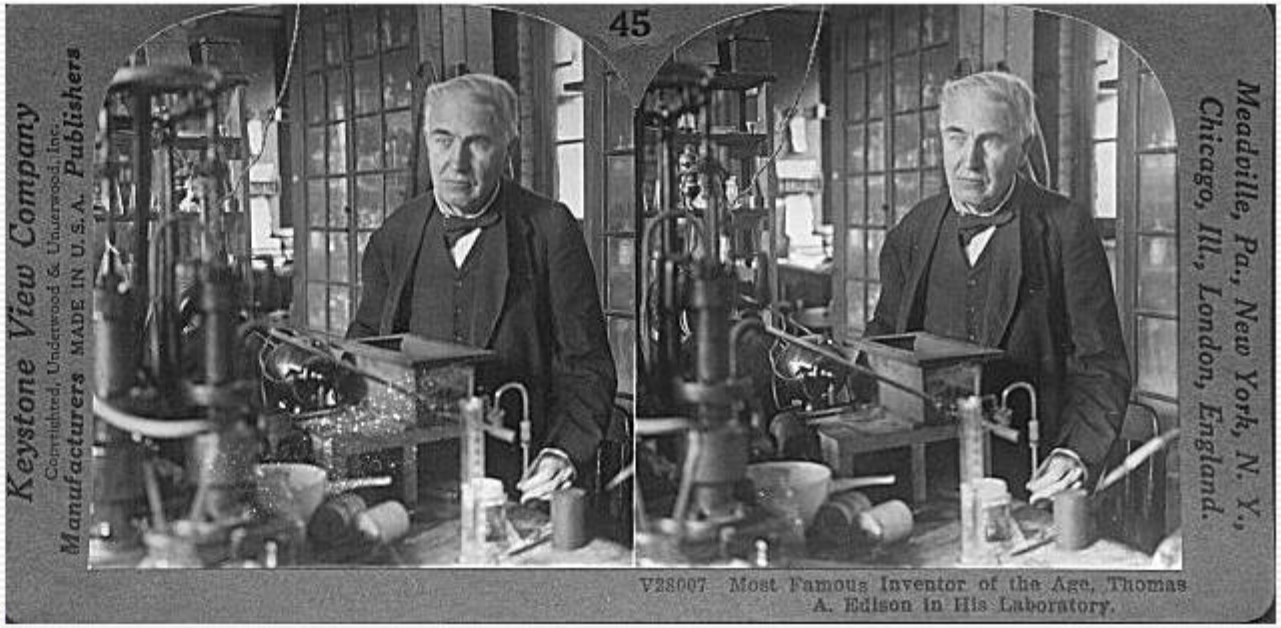
Take two pictures of the same subject from two slightly different viewpoints and display so that each eye sees only one of the images.



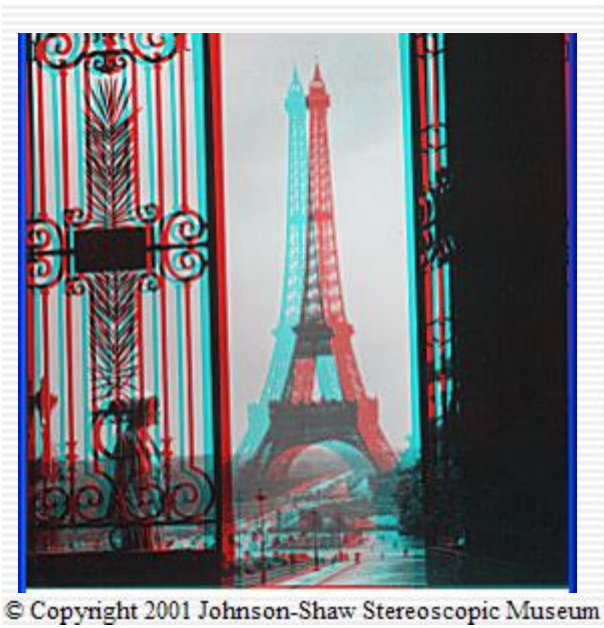
Invented by Sir Charles Wheatstone, 1838

Image from fisher-price.com

Anaglyph stereo



http://www.johnsonshawmuseum.org



http://www.johnsonshawmuseum.org

Wiggle images

http://www.well.com/~jimg/stereo/stereo_list.html

Stereo vision

Two cameras, simultaneous views

Single moving camera and static scene

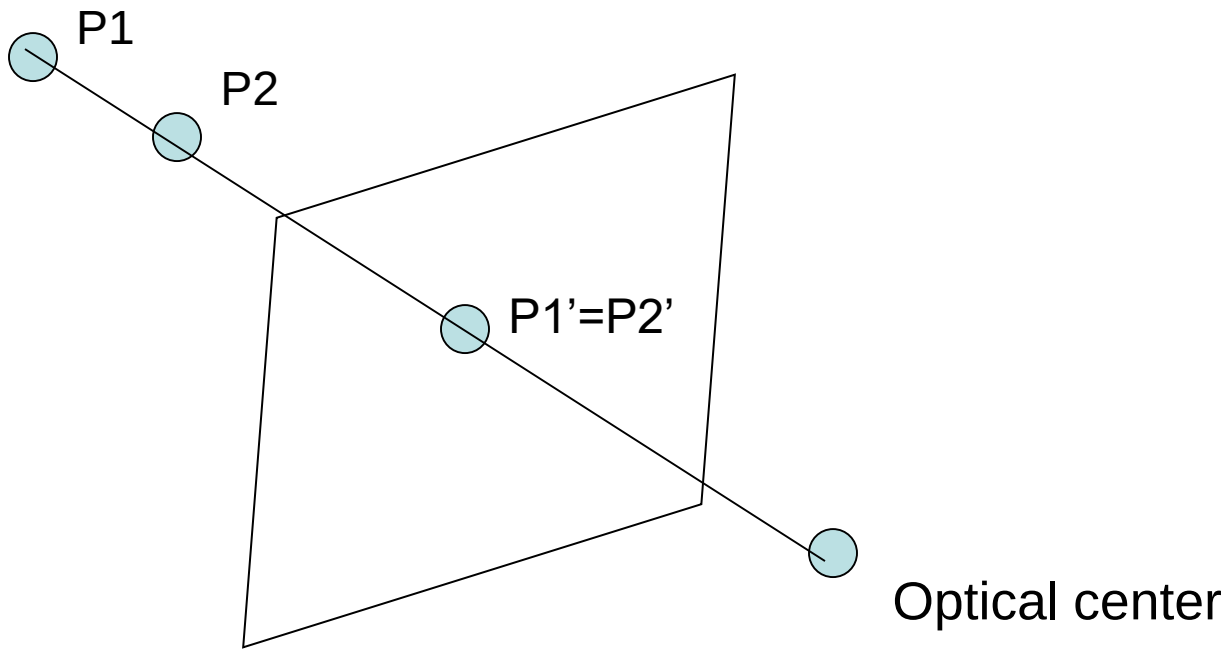
Why multiple views?

Structure and depth can be ambiguous from single views...

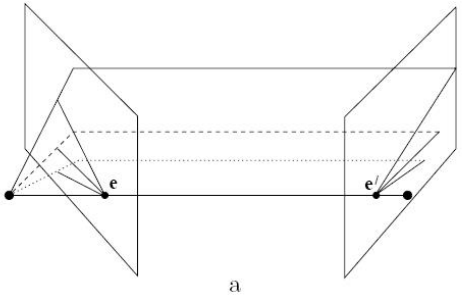
Images from Lana Lazebnik

Why multiple views?

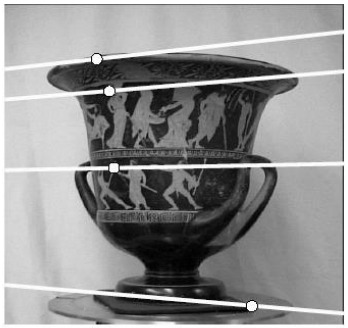
Points at different depths along a line project to a single point



Multiple views



a

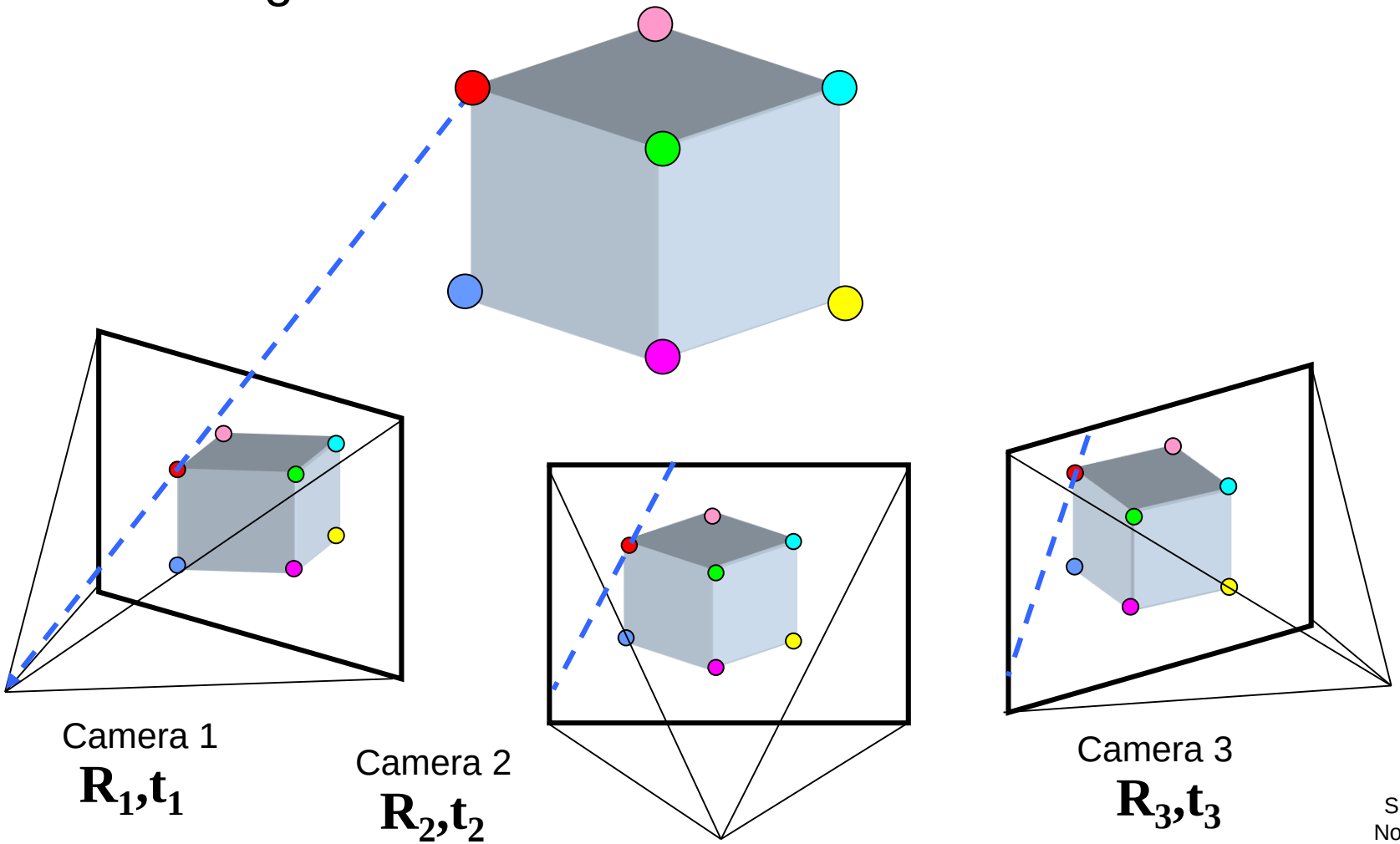


Hartley and Zisserman

Stereo vision
Structure from motion
Optical flow

Multi-view geometry problems

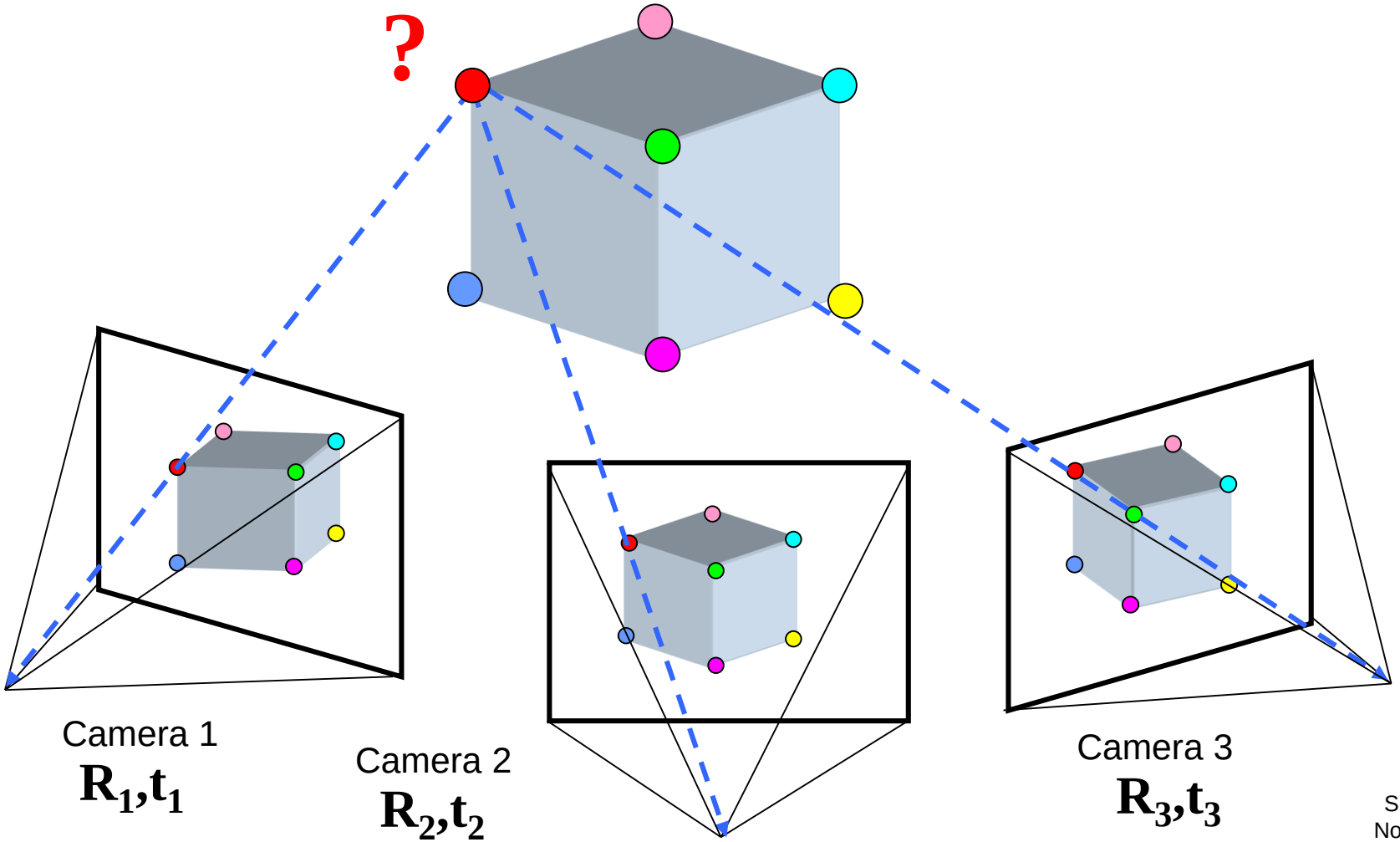
- **Stereo correspondence:** Given a point in one of the images, where could its corresponding points be in the other images?



Slide credit: Noah Snavely

Multi-view geometry problems

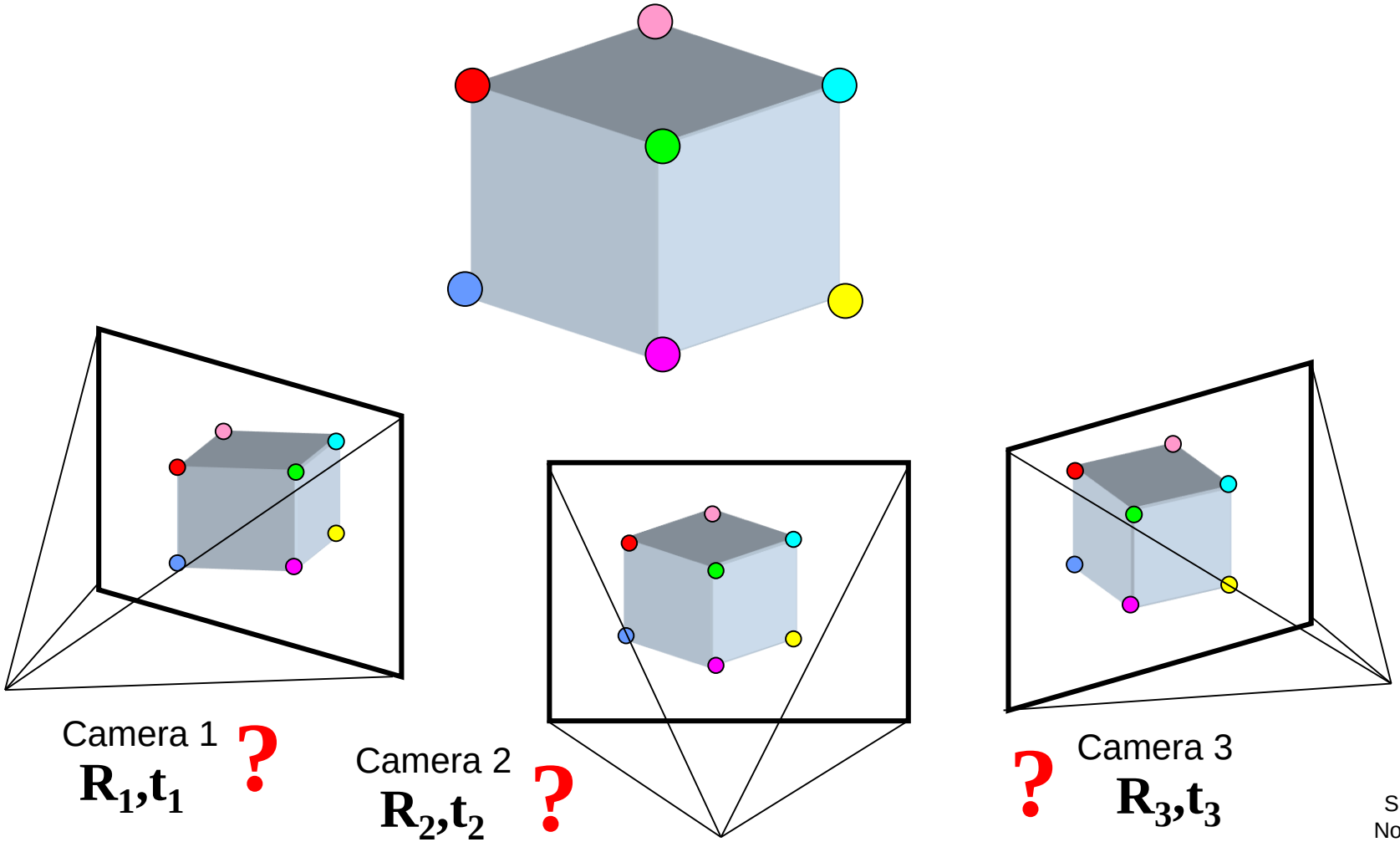
- **Structure:** Given projections of the same 3D point in two or more images, compute the 3D coordinates of that point



Slide credit: Noah Snavely

Multi-view geometry problems

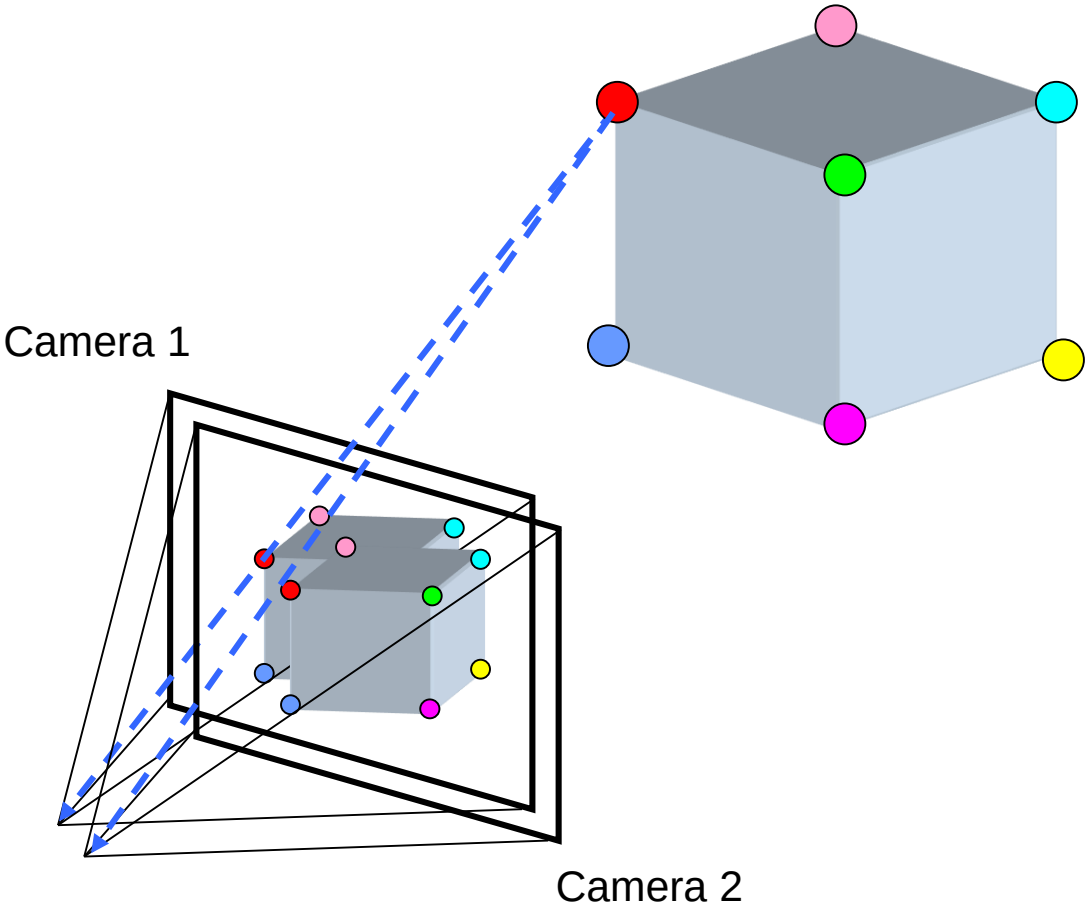
- **Motion:** Given a set of corresponding points in two or more images, compute the camera parameters



Slide credit: Noah Snavely

Multi-view geometry problems

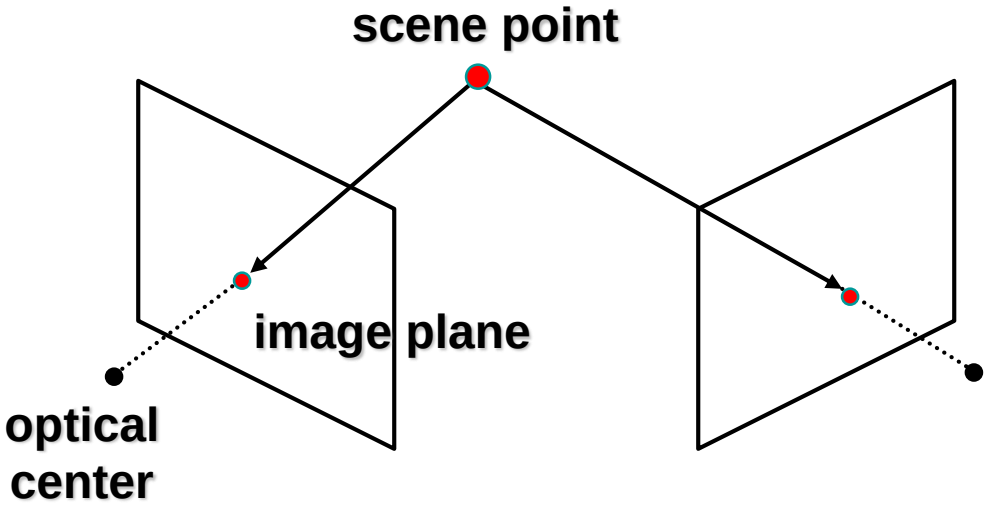
- **Optical flow:** Given two images, find the location of a world point in a second close-by image with no camera info.

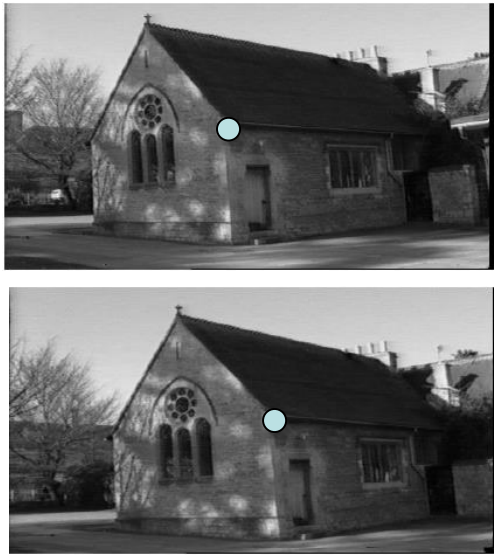


Multiple views - Dogception

Estimating depth with stereo

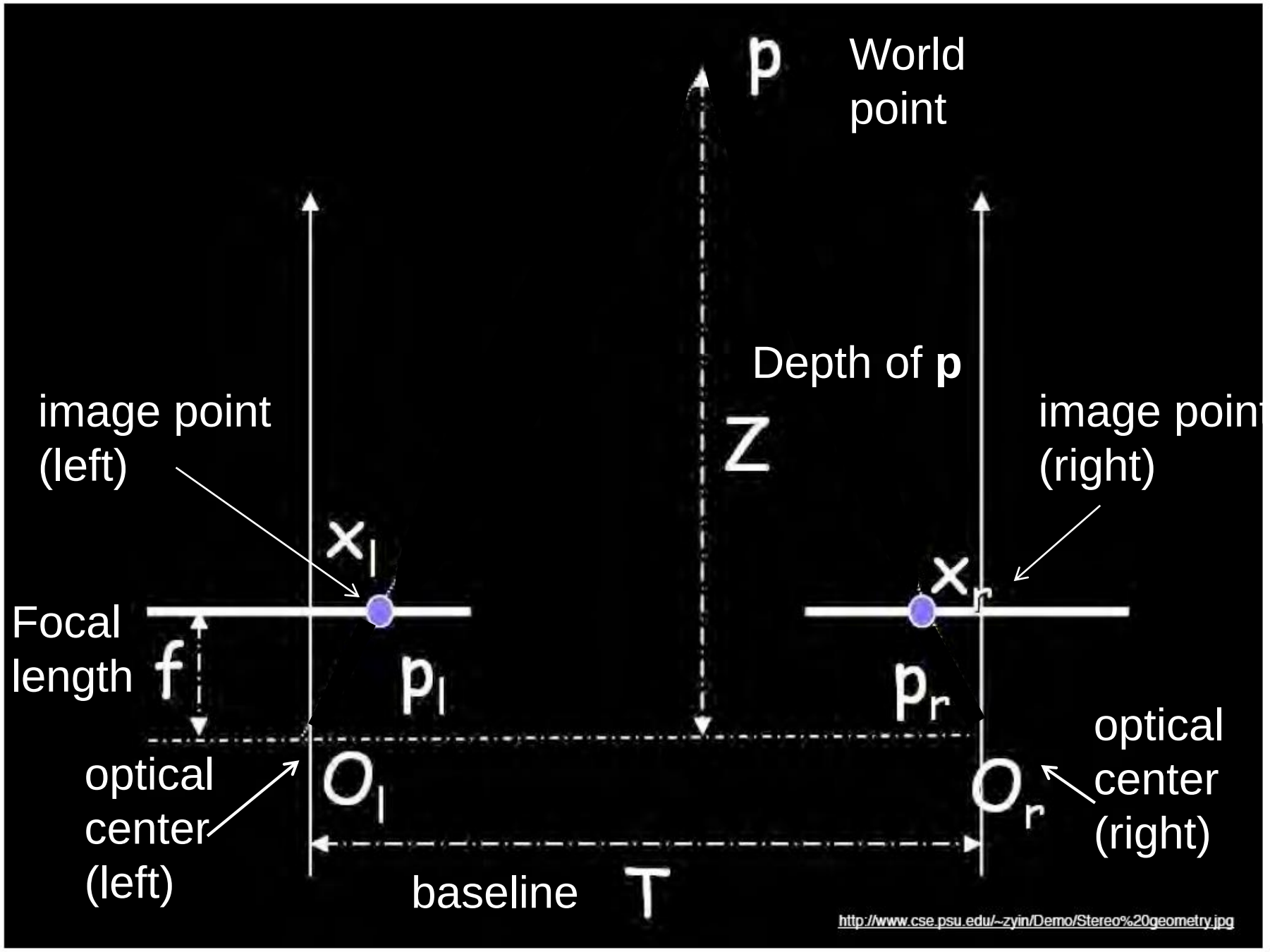
- **Stereo**: shape from “motion” between two views
- We’ll need to consider:
  - Info on camera pose (“calibration”)
  - Image point correspondences





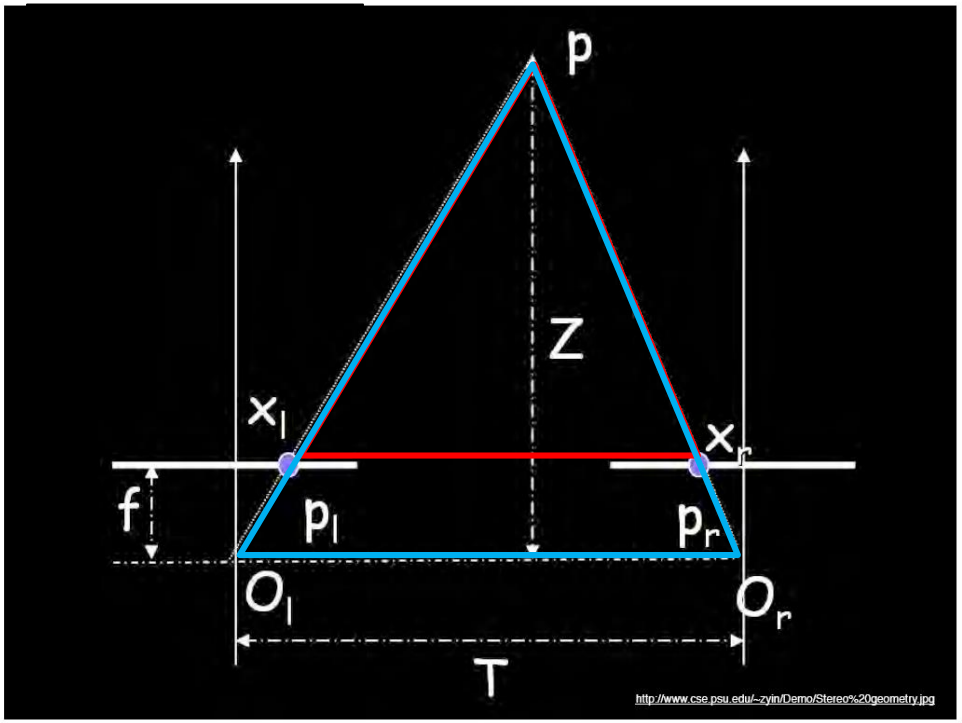
Geometry for a simple stereo system

- Let’s look at a simple stereo system first.
- Assume:
  - parallel optical axes,
  - known camera parameters (i.e., calibrated cameras):


p
World point
Depth of p
Z
image point (left)
image point (right)
x_l
x_r
Focal length
f
p_l
p_r
optical center (left)
O_l
O_r
optical center (right)
baseline
T
http://www.cse.psu.edu/~zyin/Demo/Stereo%20geometry.jpg

Geometry for a simple stereo system

- Assume parallel optical axes, known camera parameters (i.e., calibrated cameras). **What is expression for Z?**



Similar triangles (p_l, P, p_r) and (O_l, P, O_r):

$$\frac{T + x_l - x_r}{Z - f} = \frac{T}{Z}$$

$$Z = f\frac{T}{x_r - x_l}$$

disparity

Depth from disparity

image I(x,y)

Disparity map D(x,y)

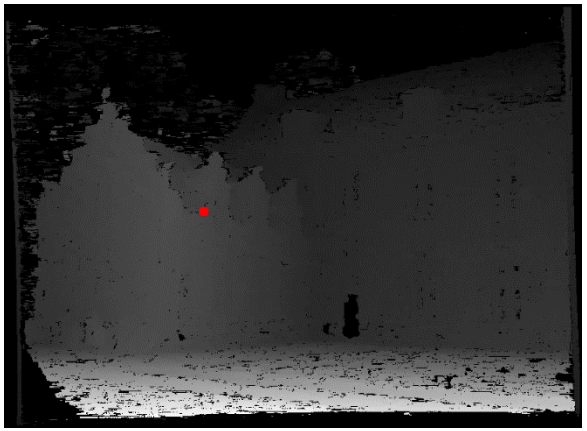


image I´(x´,y´)

$(x´,y´)=(x+D(x,y), y)$

So if we could find the **corresponding points** in two images, we could **estimate relative depth**…