



Multi-View Geometry (Ch7 New book. Ch 10/11 old book)

Guido Gerig

CS 6320 Spring 2013

Credits: M. Shah, UCF CAP5415, lecture 23

<http://www.cs.ucf.edu/courses/cap6411/cap5415/>, Trevor Darrell, Berkeley, C280, Marc Pollefeys



Material I

- <http://vision.middlebury.edu/stereo/>
- (online stereo pairs and truth (depth maps))
- Stereo correspondence software: e.g. <http://vision.middlebury.edu/stereo/data/scenes2001/data/imagehtml/tsukuba.html>
- CVonline compendium: <http://homepages.inf.ed.ac.uk/rbf/CVonline/>

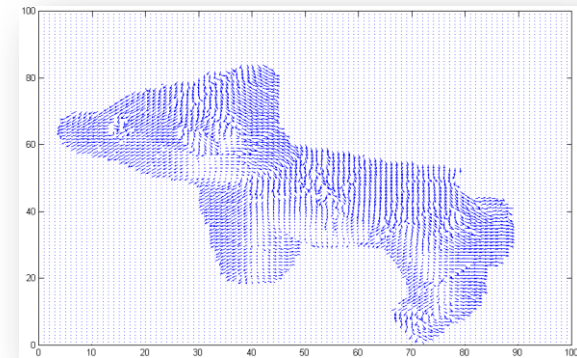
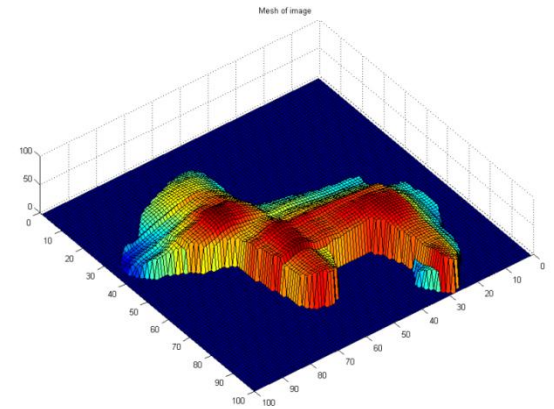


Material II

- Epipolar Geometry, Rectification:
- http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/FUSIELLO2/rectif_cvol.html
- and:
http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/OWENS/LECT11/node11.html
- Stereo:
- http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/OWENS/LECT11/lect11.html
- 3D Reconstruction:
- http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/OWENS/LECT11/node8.html

Visual cues

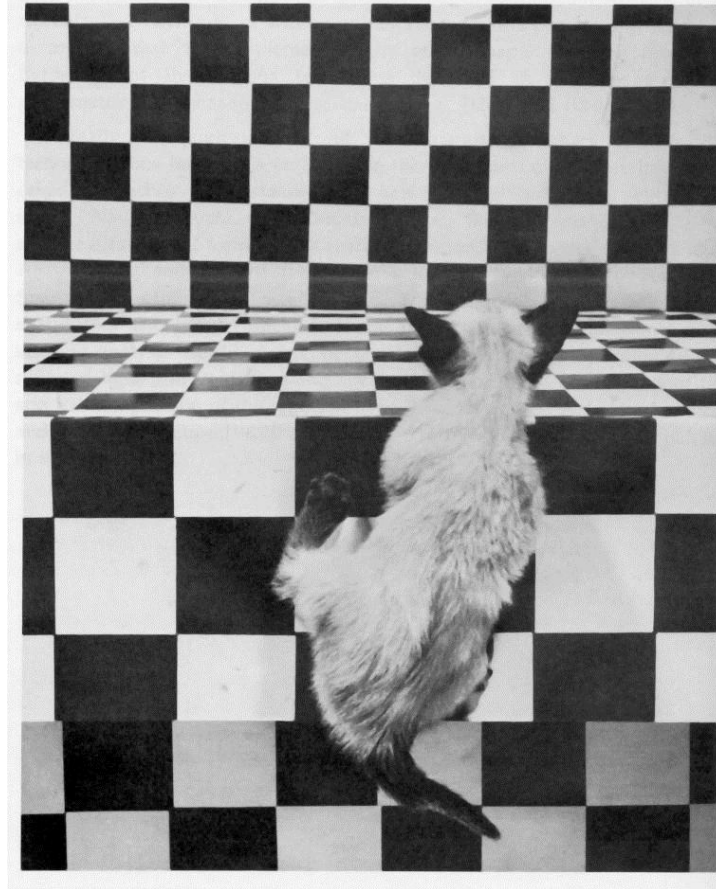
- Shading





Visual cues

- Shading
- Texture



The Visual Cliff, by William Vandivert, 1960



Visual cues

- Shading
- Texture
- Focus



From *The Art of Photography*, Canon



Visual cues

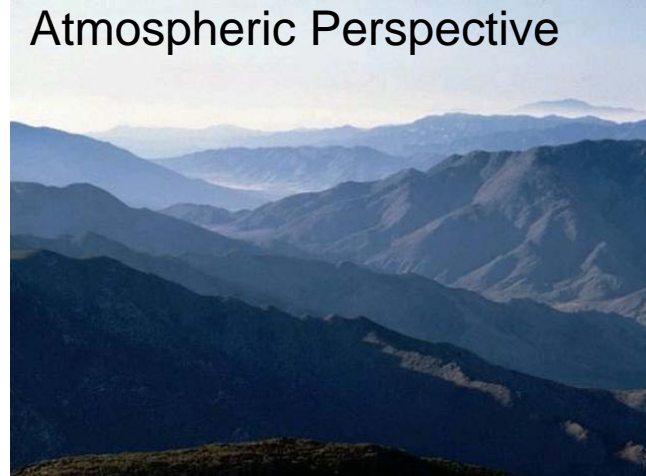
- Shading
- Texture
- Focus
- Motion



Visual cues

- Shading
- Texture
- Focus
- Motion
- **Shape From X** (X = shading, texture, focus, motion, rotation, ...)

Atmospheric Perspective



Linear Perspective





Visual cues

Shadows





Visual cues

- Shading
- Texture
- Focus
- Motion
- Shape From X (X = shading, texture, focus, motion, rotation, ...)
- **Stereo (disparity, multi-view)**



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

Stereo photography and stereo viewers



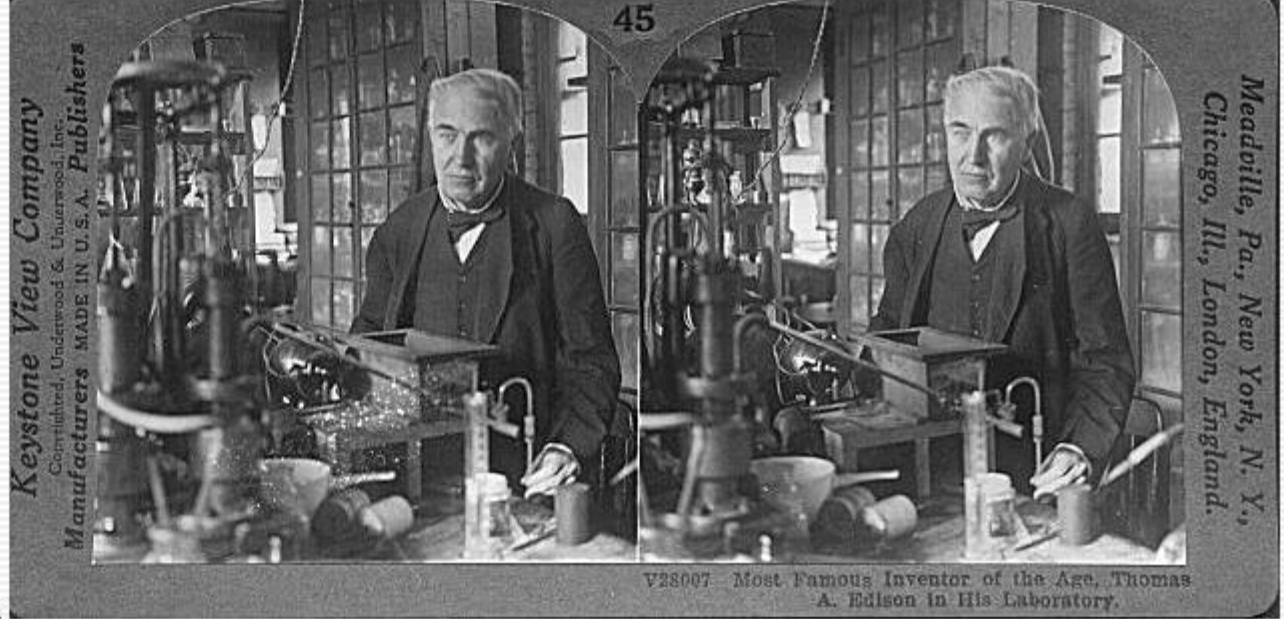
Take two pictures of the same subject from two slightly different viewpoints and display so that each eye sees only one of the images.



Invented by Sir Charles Wheatstone, 1838



Image courtesy of fisher-price.com

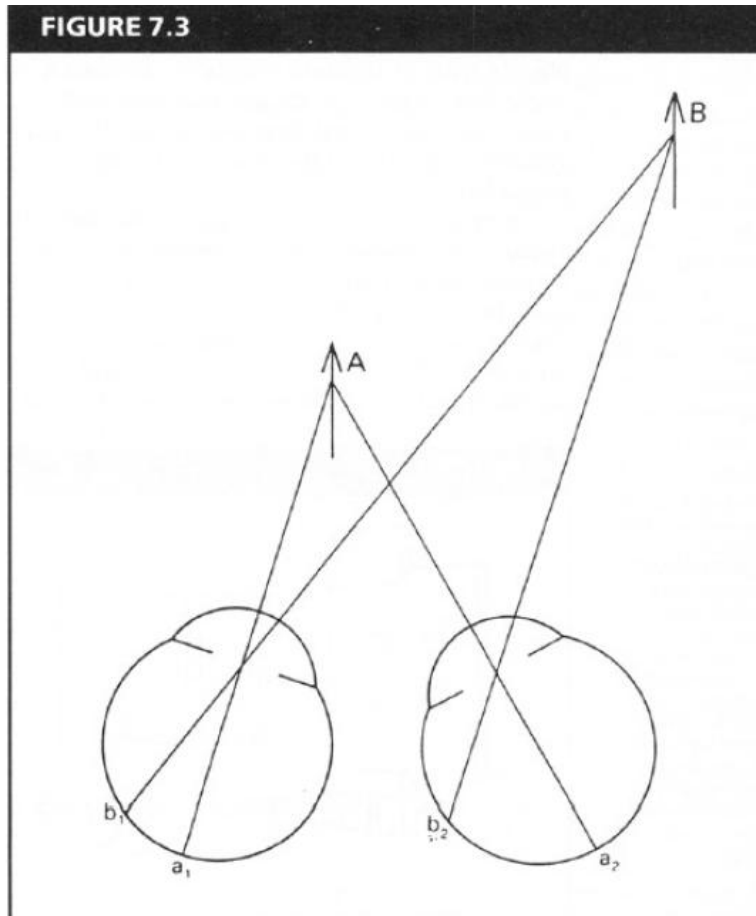


© Copyright 2001 Johnson-Shaw Stereoscopic Museum

<http://www.johnsonshawmuseum.org>

Grauman

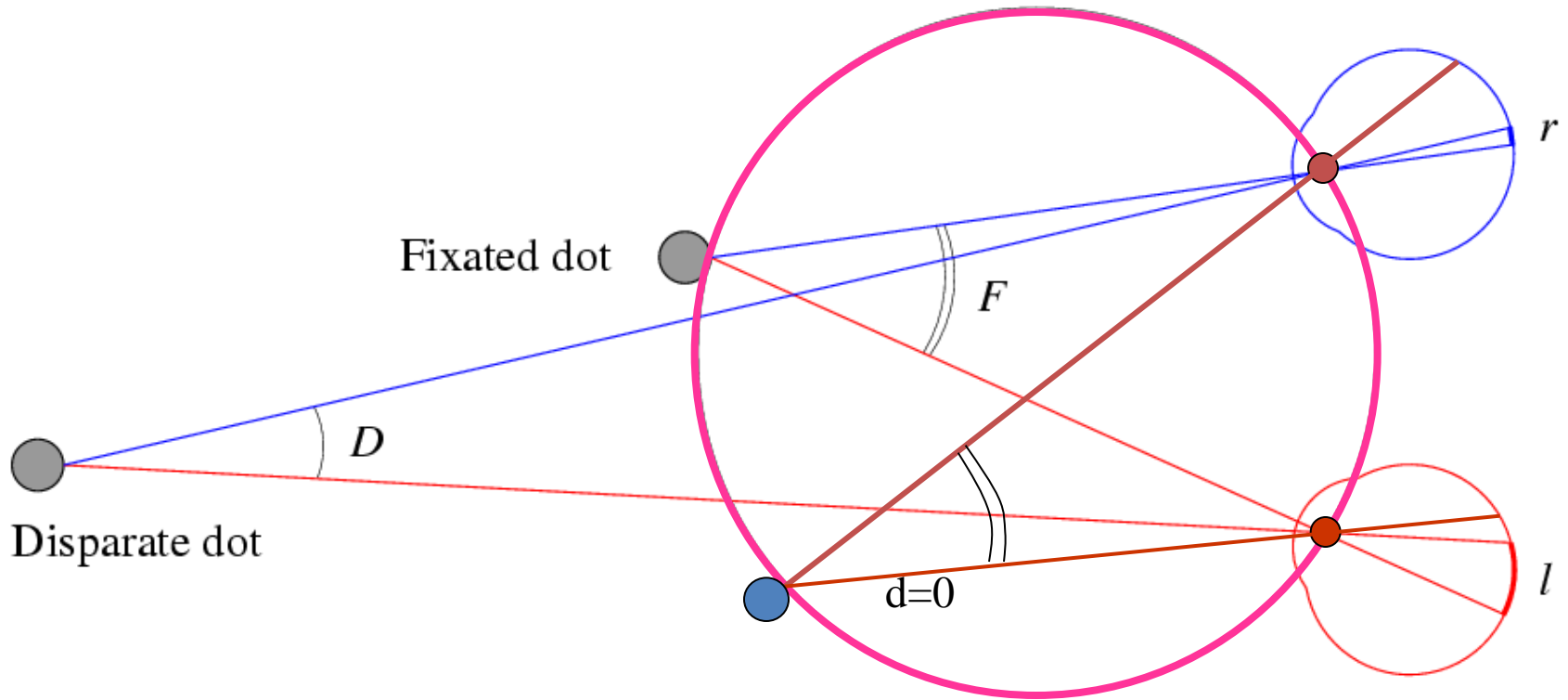
Human stereopsis: disparity



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

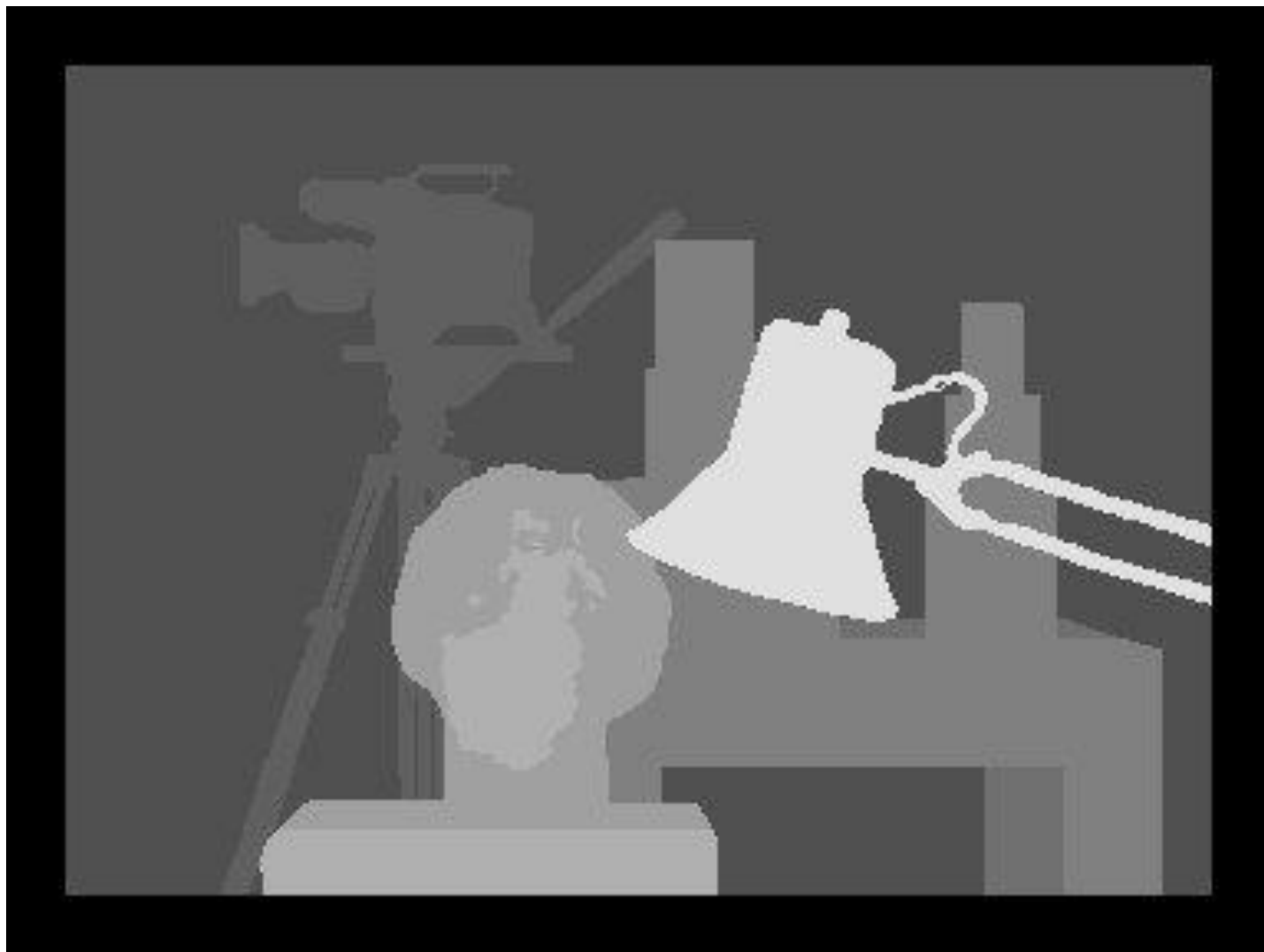
From Bruce and Green, Visual Perception, Physiology, Psychology and Ecology

Human stereopsis: disparity

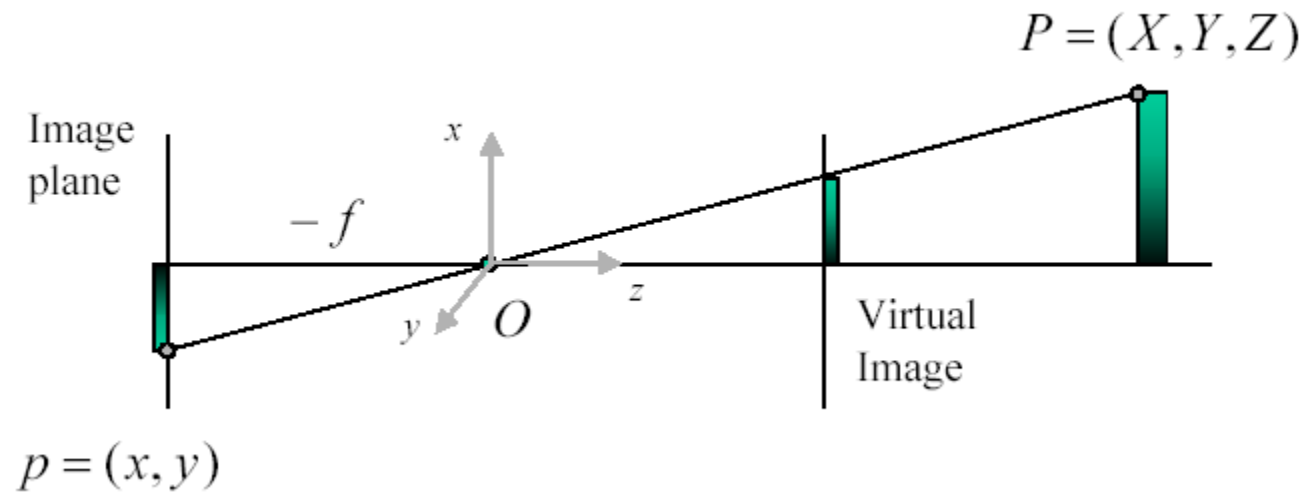


Disparity: $d = r - l = D - F$.

Example: Stereo to Depth Map

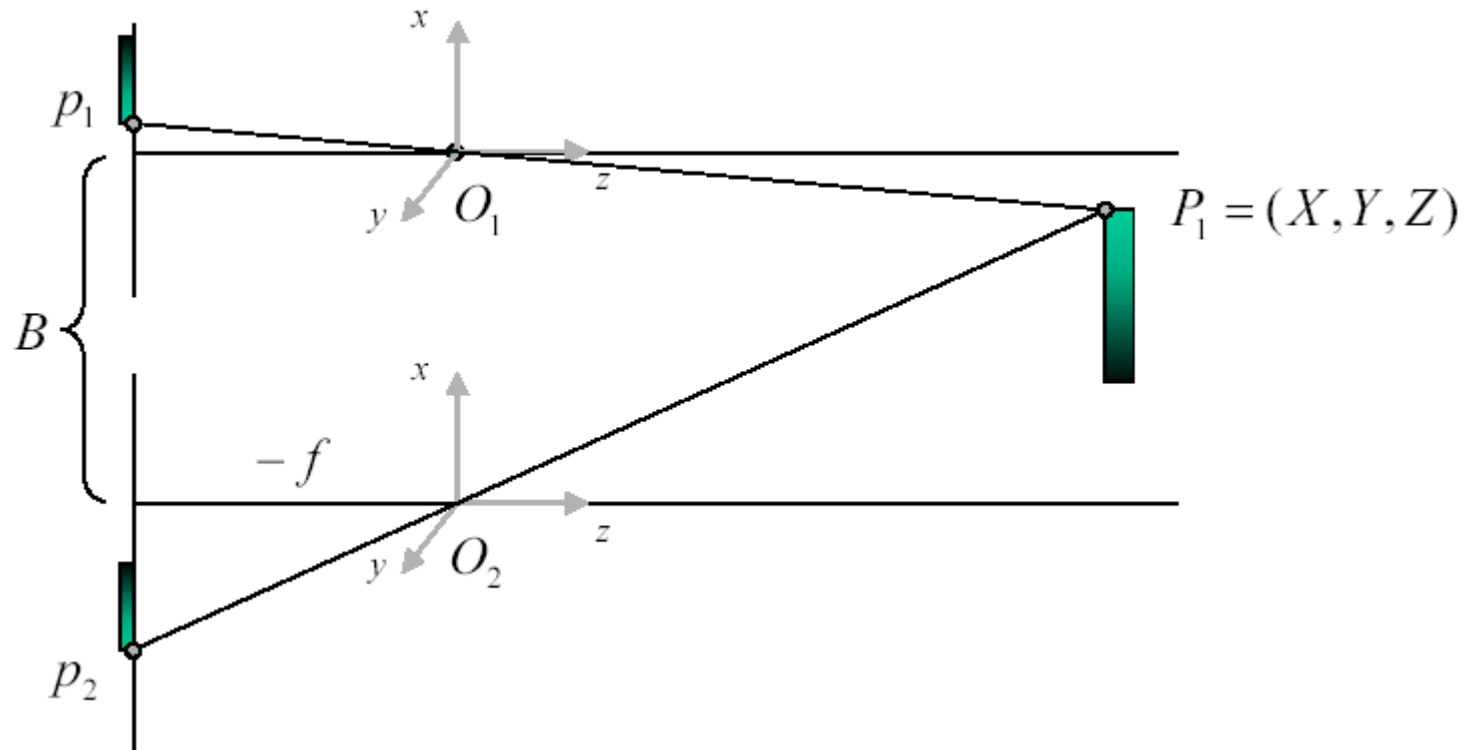


Pinhole Camera Model



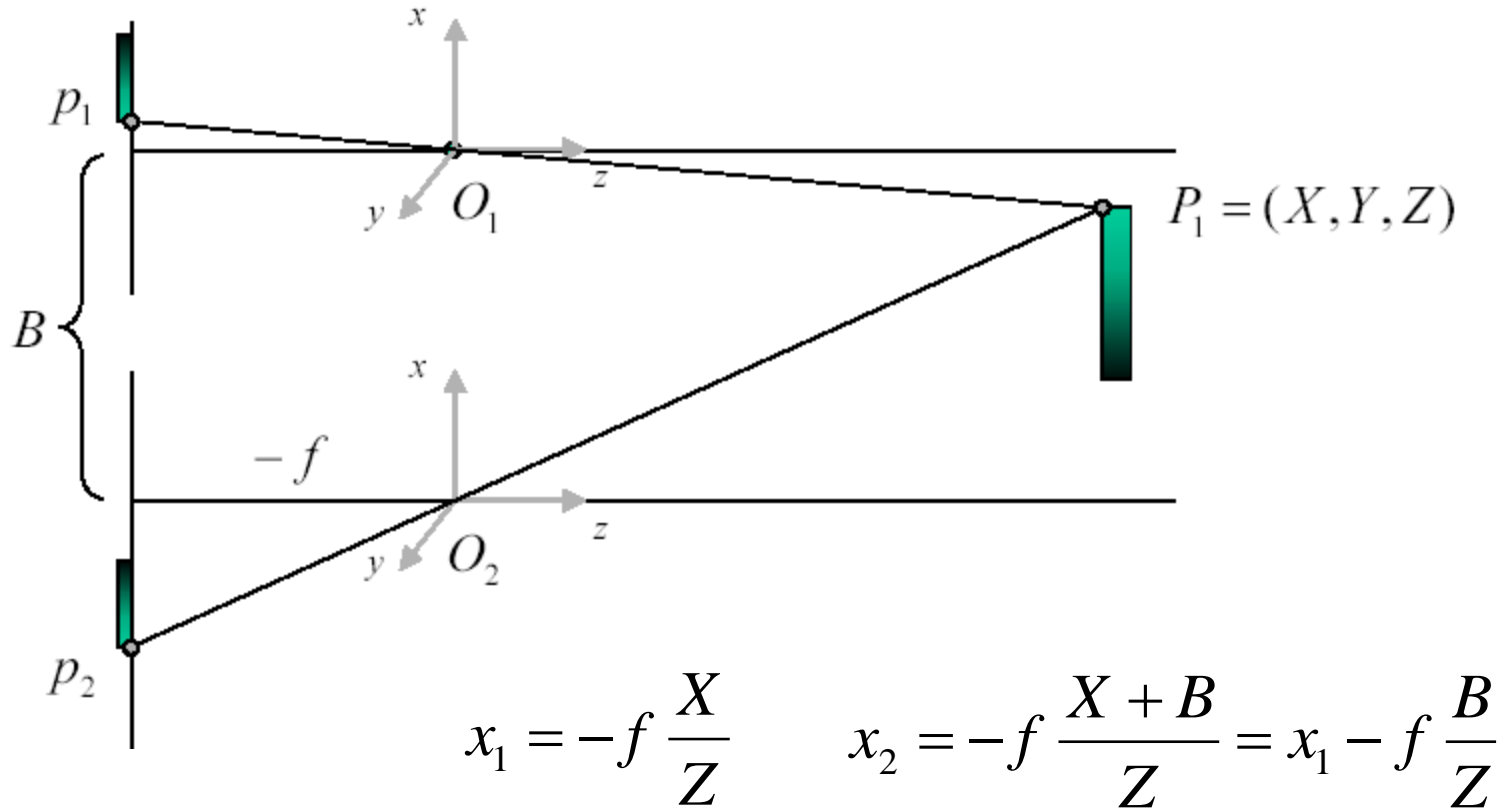
$$x = -f \frac{X}{Z}$$

Basic Stereo Derivations



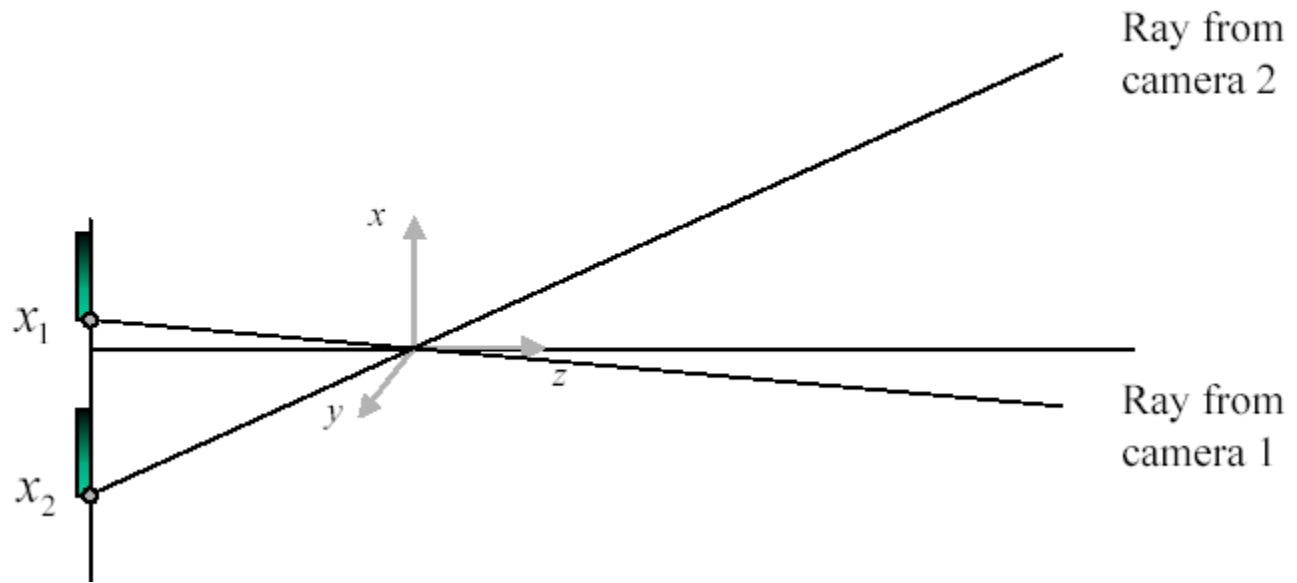
Derive expression for Z as a function of x_1 , x_2 , f and B

Basic Stereo Derivations



$$Z = \frac{fB}{x_1 - x_2}$$

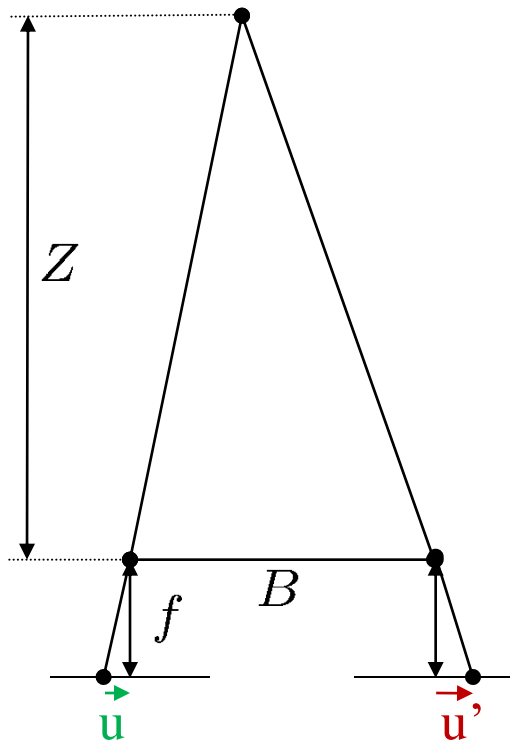
Basic Stereo Derivations



Define the disparity: $d = x_1 - x_2$

$$Z = \frac{fB}{d}$$

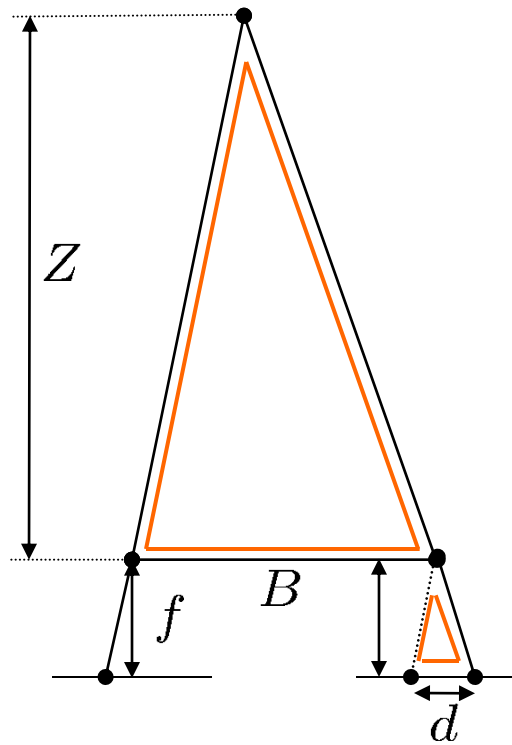
Standard stereo geometry



Disparity d:

$$d = |u' - u|$$

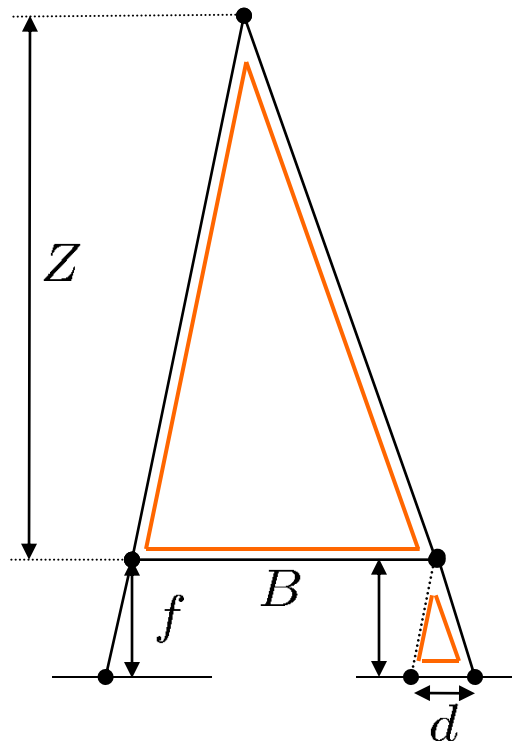
Standard stereo geometry



$$\frac{B}{Z} = \frac{d}{f}$$

$$d = \frac{Bf}{Z}$$

Standard stereo geometry

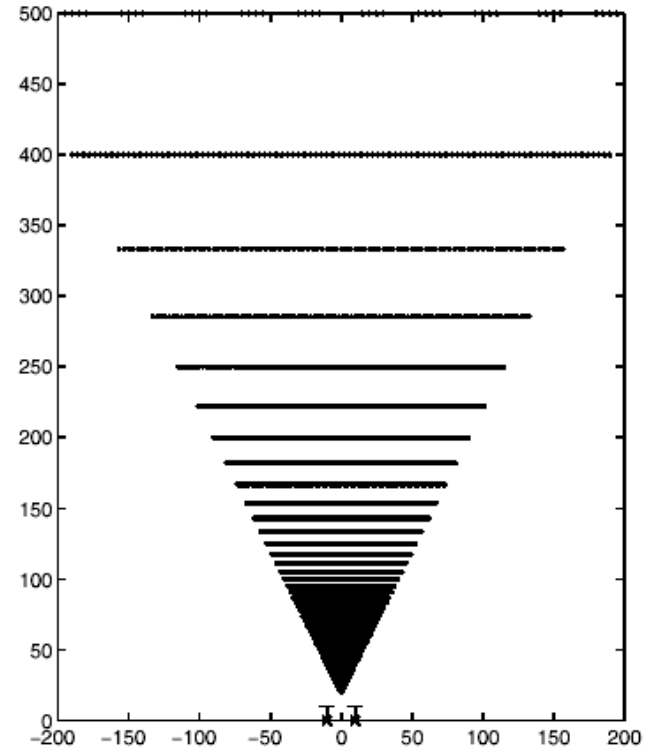


$$\frac{B}{Z} = \frac{d}{f}$$

$$d = \frac{Bf}{Z}$$

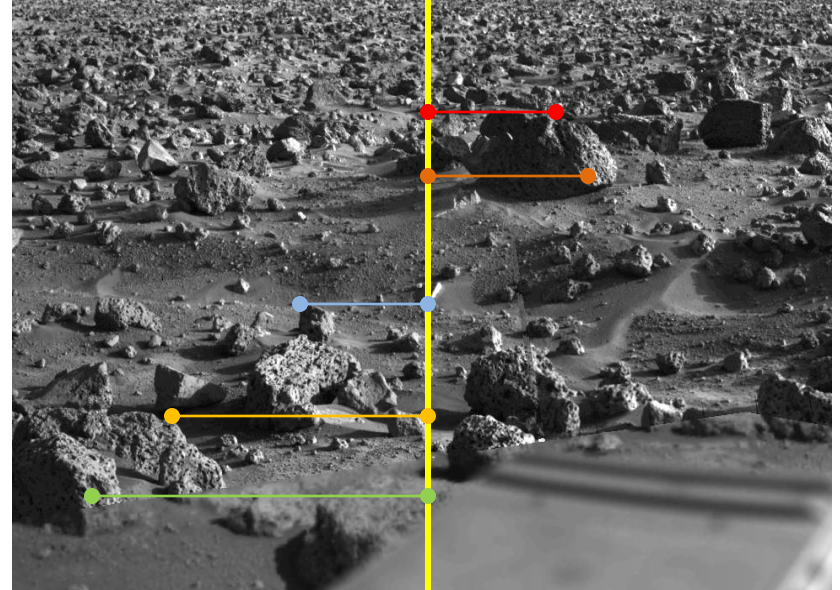
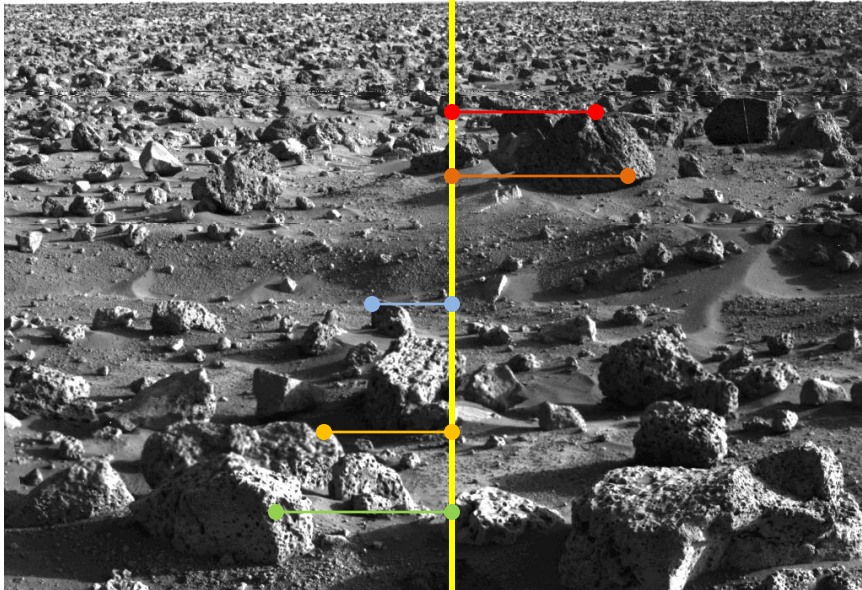
$$\frac{dd}{dZ} = \frac{Bf}{Z^2}$$

$$\Delta Z = \frac{Z^2}{Bf} \Delta d$$



Stereo Correspondence

- Search over disparity to find correspondences
- Range of disparities to search over can change dramatically within a single image pair.



Why is disparity important?



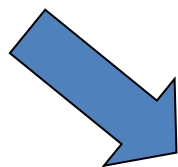
I1



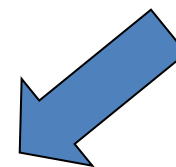
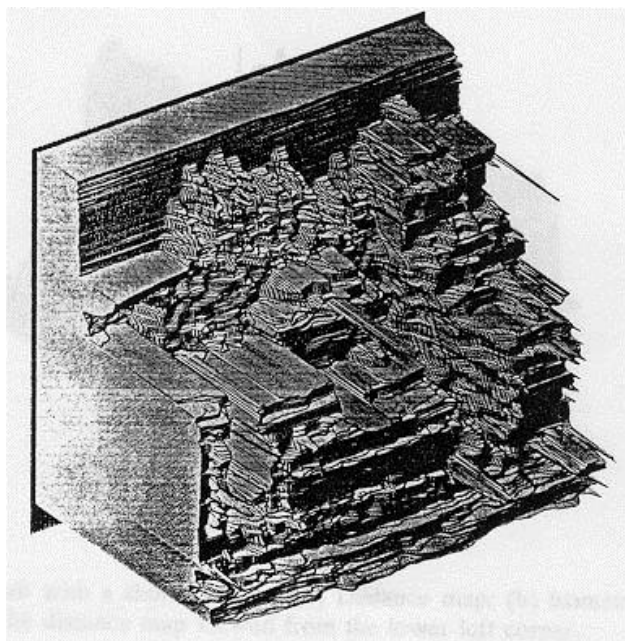
I2



I10



Given dense
disparity map,
we can
calculate a
depth/distance/
range map.



Goal: 3D from Stereo via Disparity Map

image $I(x,y)$



Disparity map $D(x,y)$

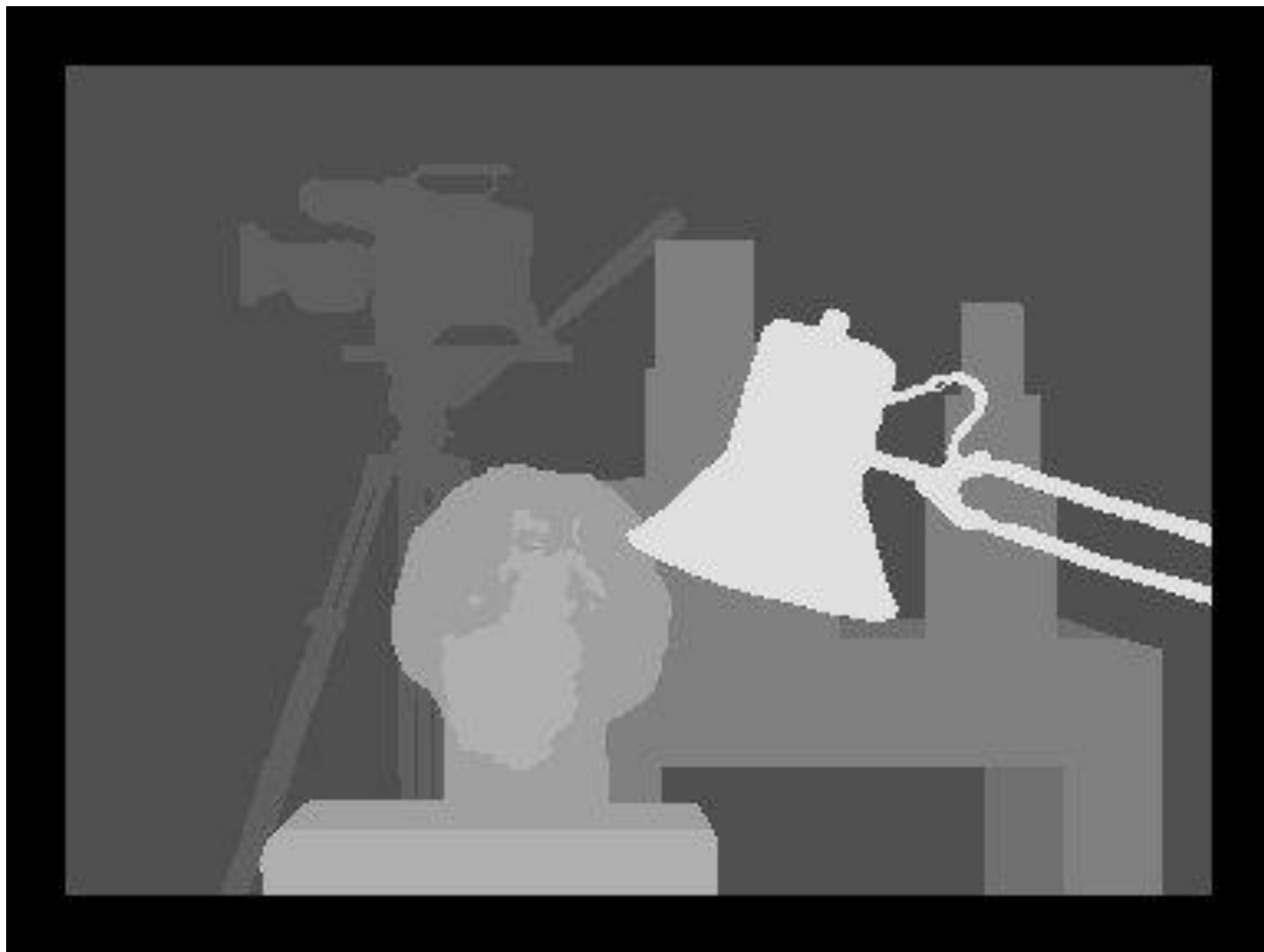


image $I'(x',y')$



$$(x',y')=(x+D(x,y),y)$$

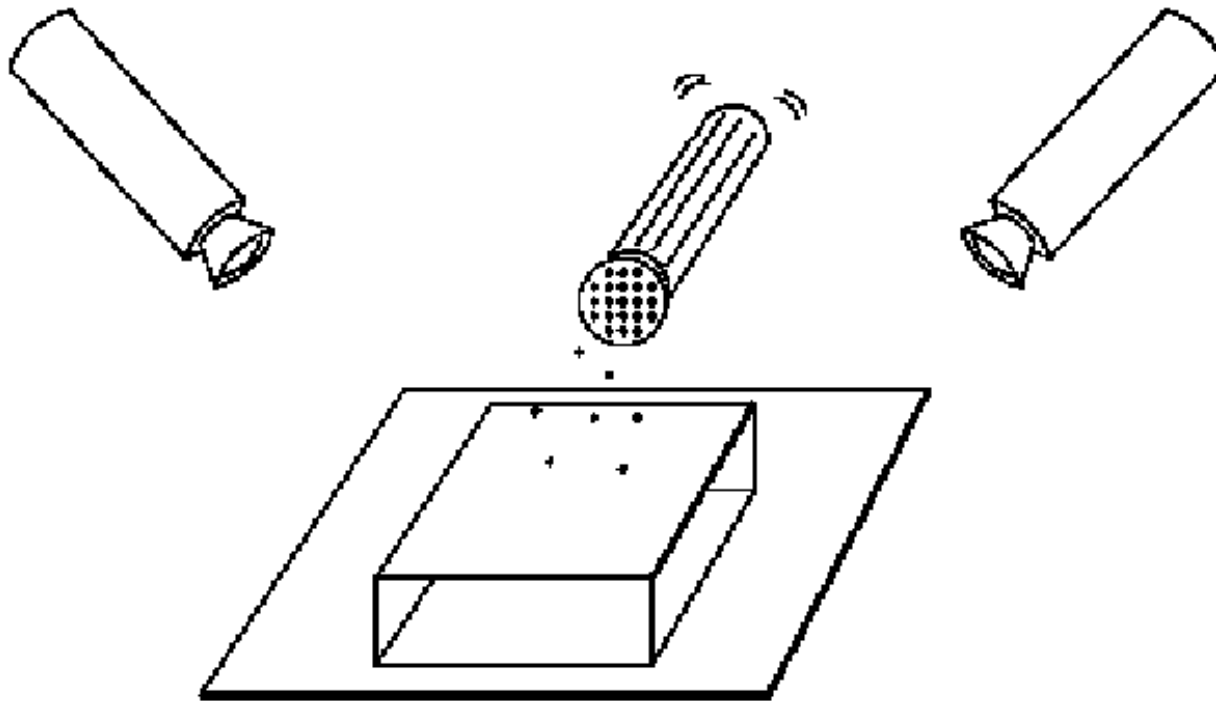
Example: Stereo to Depth Map



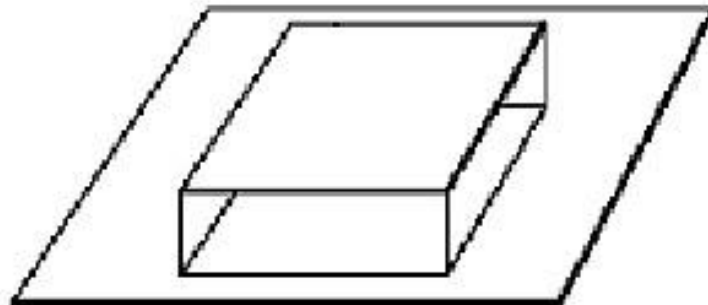
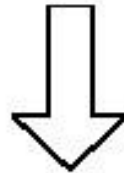
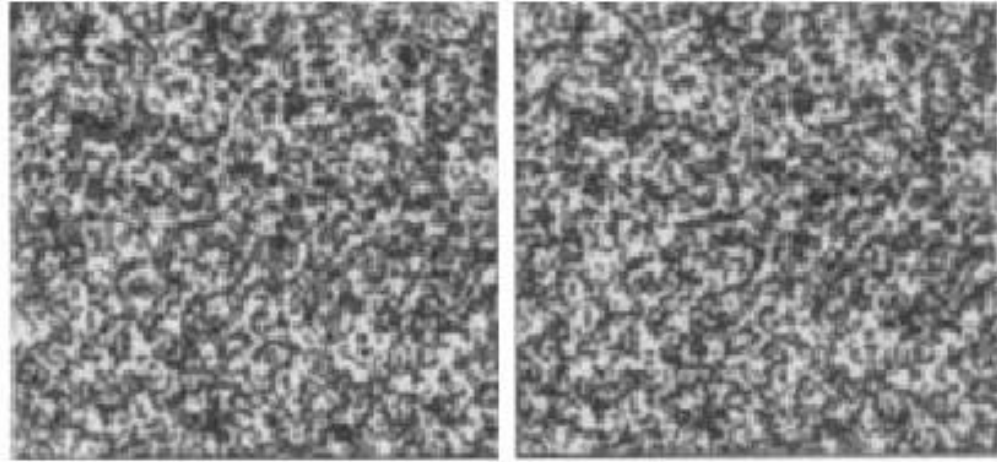
Random dot stereograms

- 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

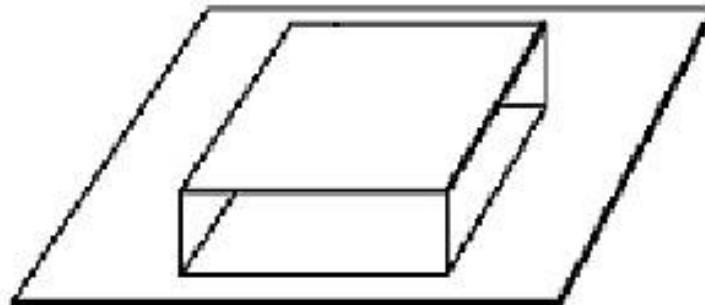
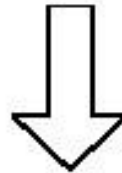
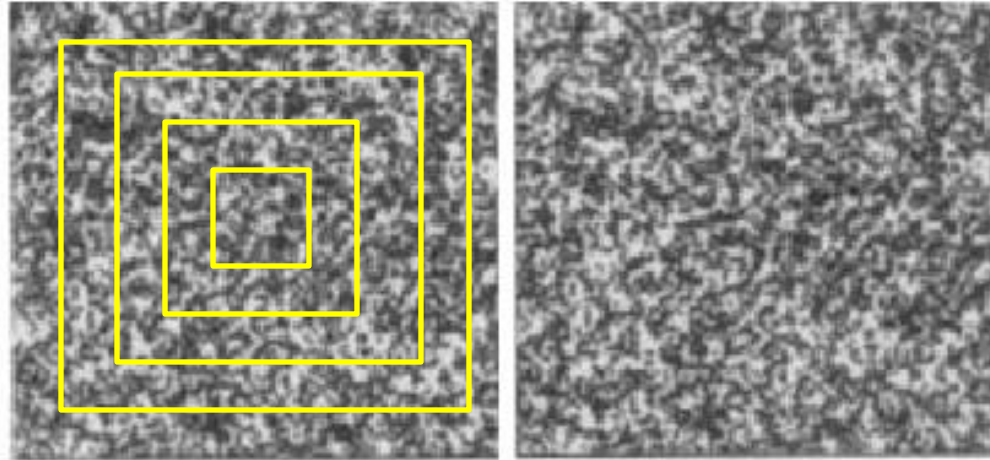
Random dot stereograms



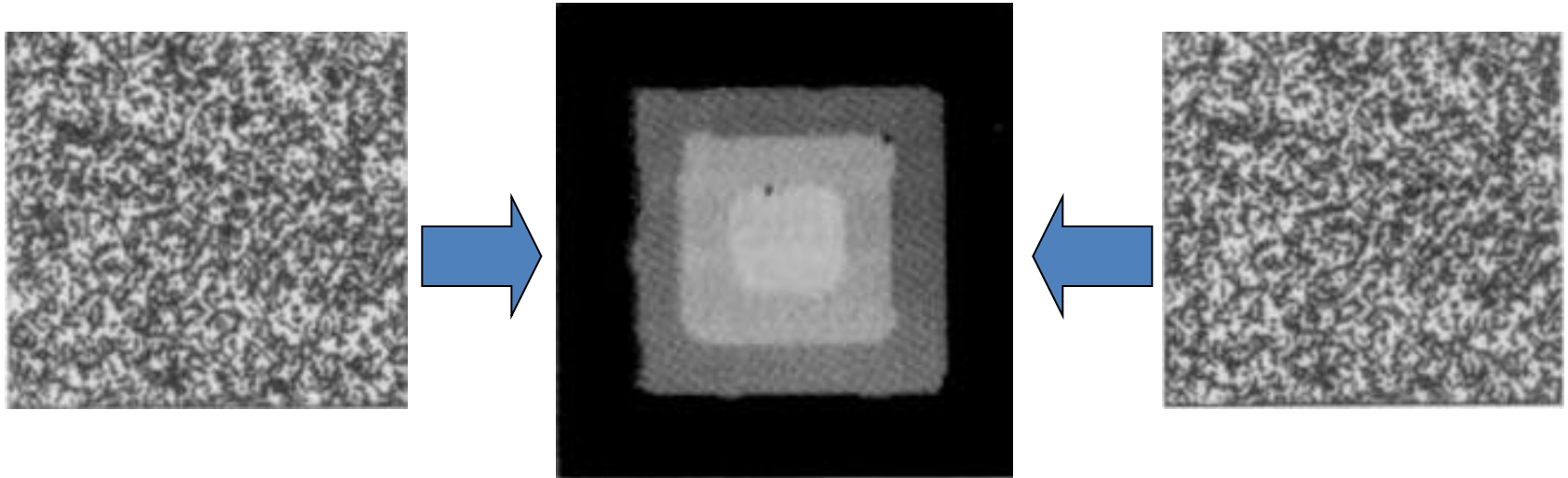
Random dot stereograms



Random dot stereograms



A Cooperative Model (Marr and Poggio, 1976)



Random dot stereograms

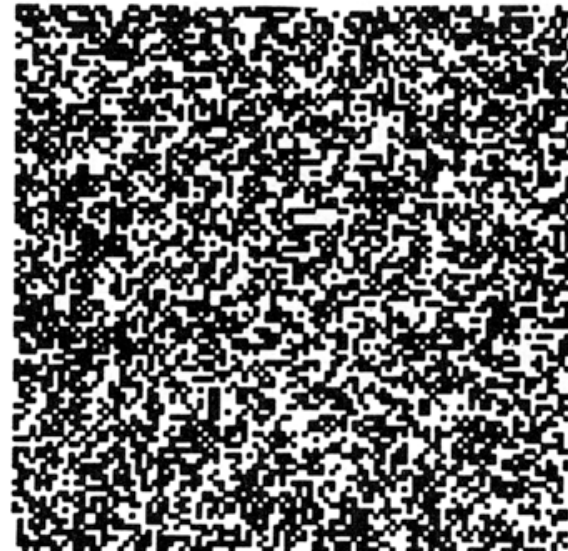
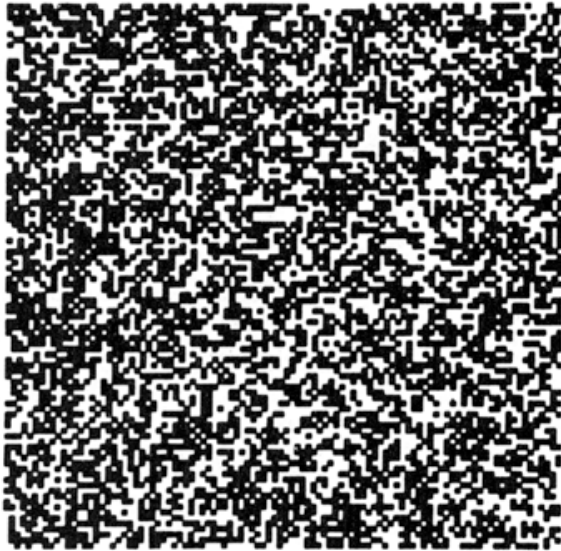


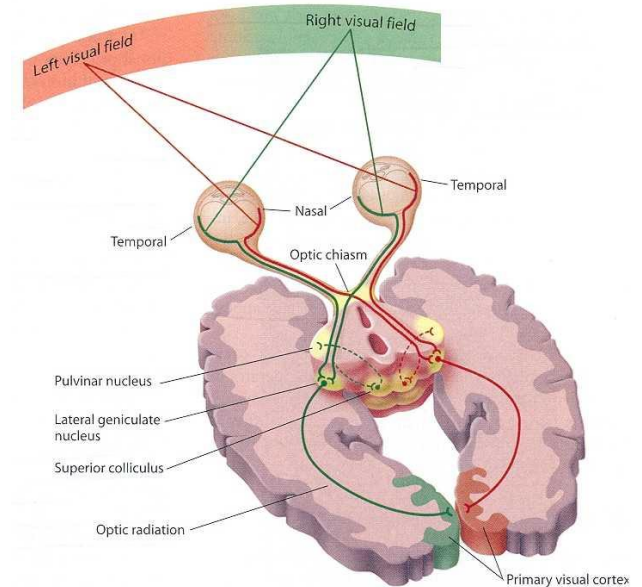
Figure 5.3.8 A random dot stereogram. These two images are derived from a single array of randomly placed squares by laterally displacing a region of them as described in the text. When they are viewed with crossed disparity (by crossing the eyes) so

that the right eye's view of the left image is combined with the left eye's view of the right image, a square will be perceived to float above the page. (See pages 210–211 for instructions on fusing stereograms.)

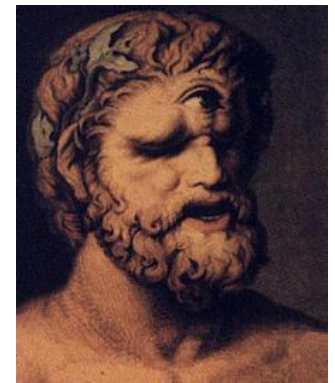
Random dot stereograms

- When viewed monocularly, they appear random; when viewed stereoscopically, see 3d structure.
- Conclusion: human binocular fusion not directly associated with the physical retinas; must involve the central nervous system
- Imaginary* “*cyclopean retina*” that combines the left and right image stimuli as a single unit

*This was because it was as though we have a cyclopean eye inside our brains that can see cyclopean stimuli hidden to each of our actual eyes.



Visual Pathway.jpg wiki.ucl.ac.uk



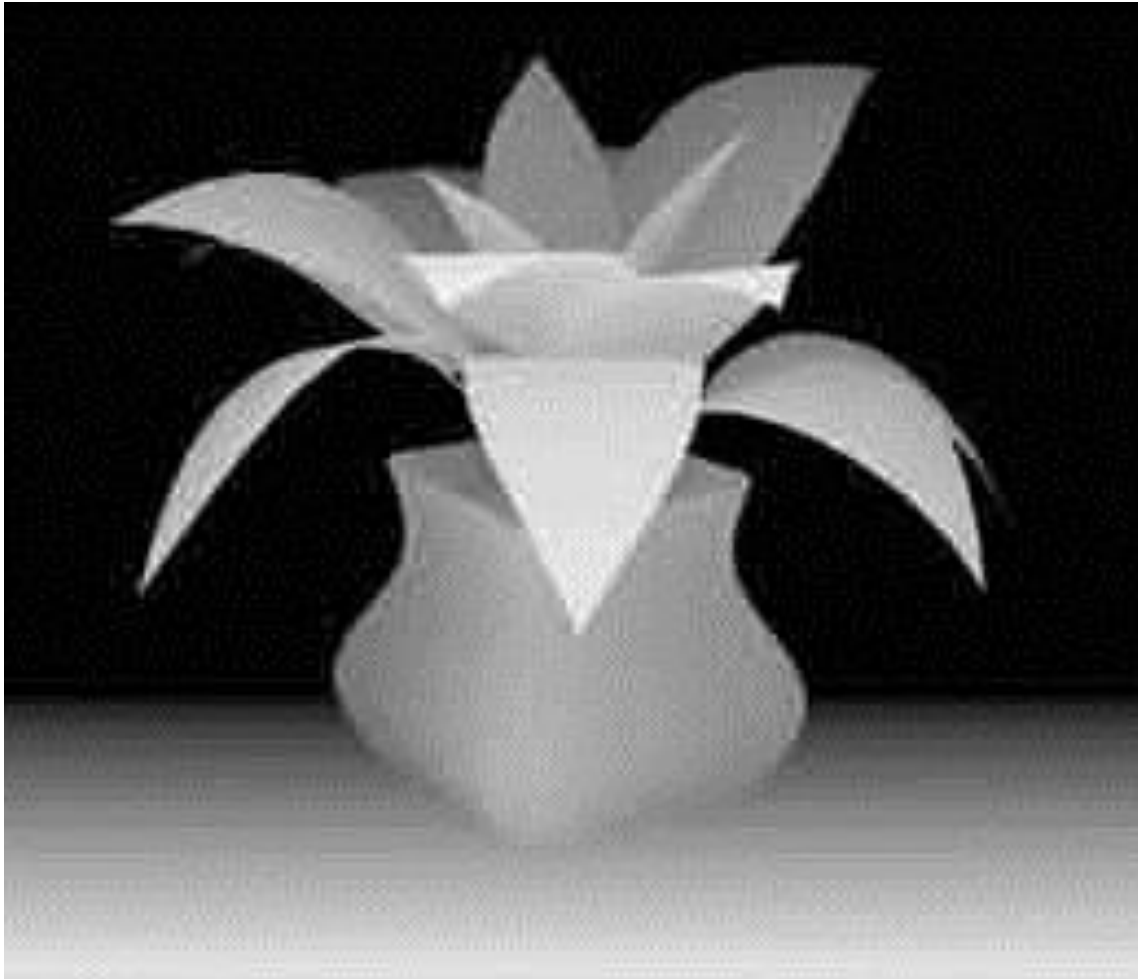
Autostereograms



Exploit disparity as depth cue using single image

(Single image random dot stereogram, Single image stereogram)

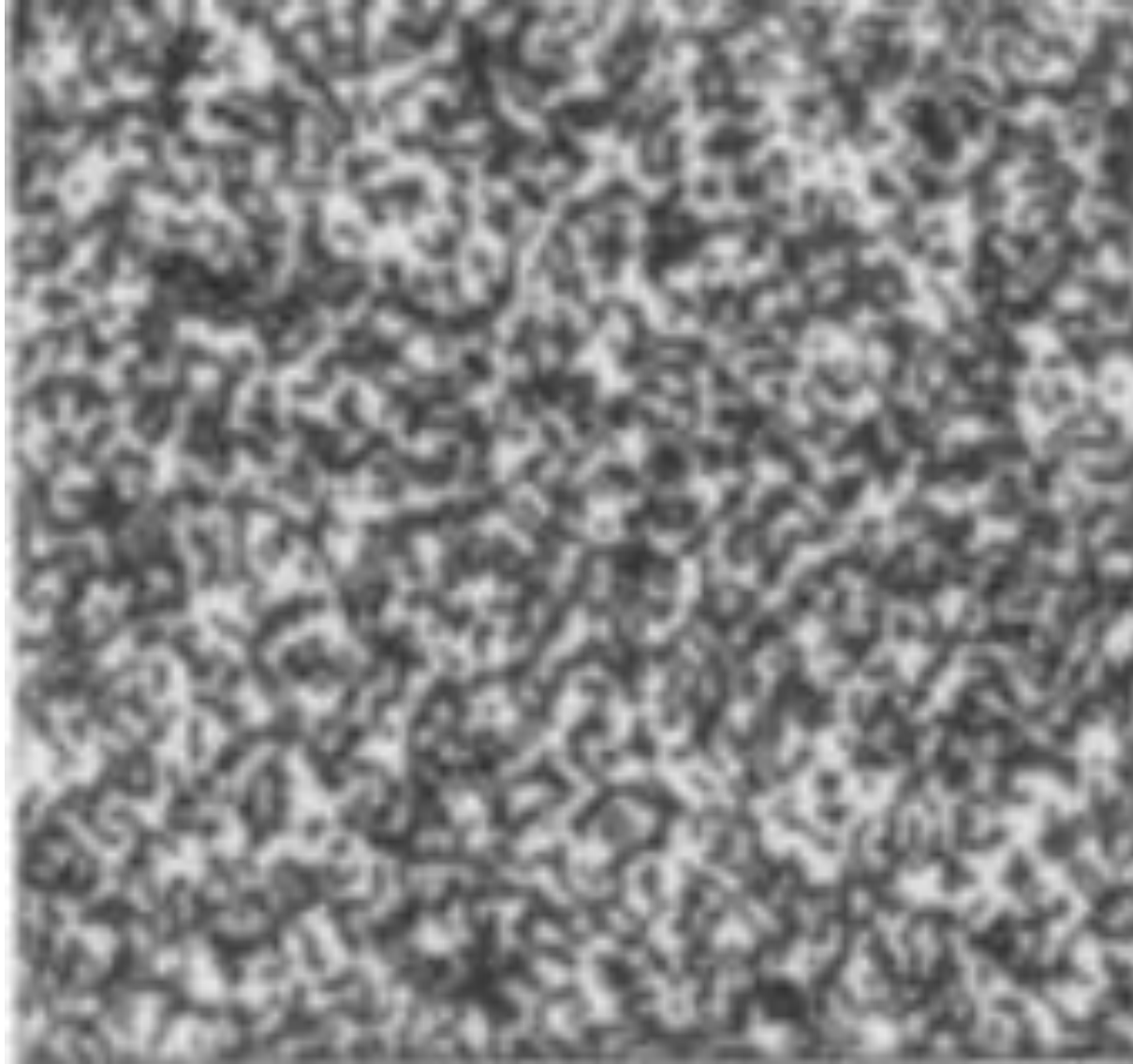
Autostereograms



Images from magiceye.com

Optical flow

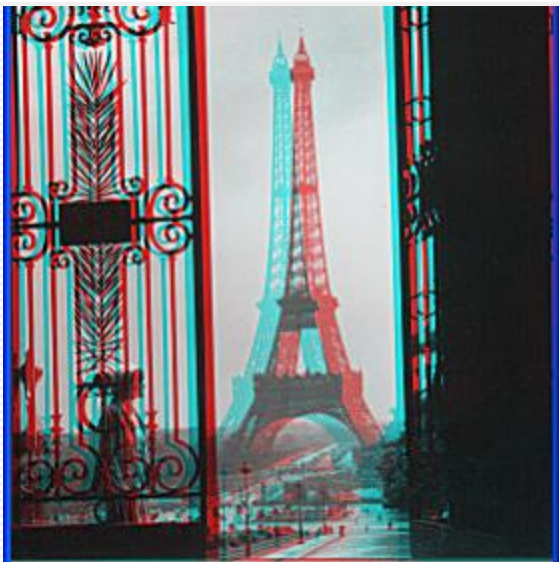
Where do pixels move?



Optical flow

Where do pixels move?





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Public Library, Stereoscopic Looking Room, Chicago, by Phillips, 1923

