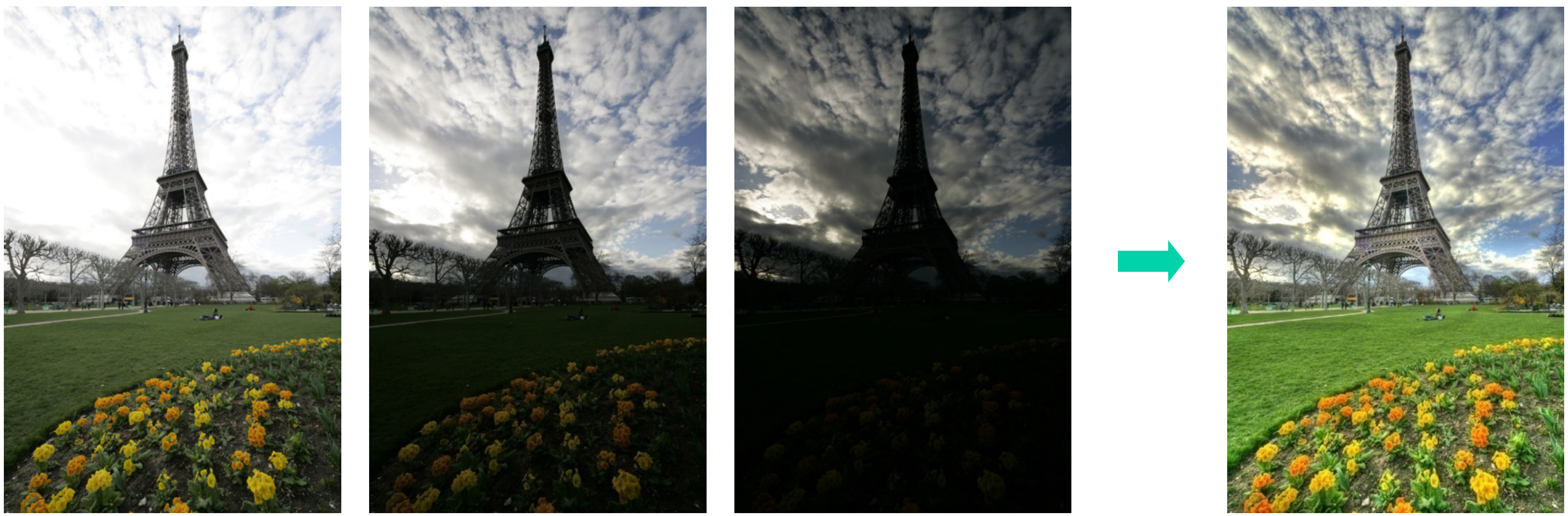
What have we learned so far?

- Camera structure
- Eye structure



Project 1: High Dynamic Range Imaging

What have we learned so far?

- Image Filtering
- Image Warping
- Camera Projection Model

Project 2: Panoramic Image Stitching

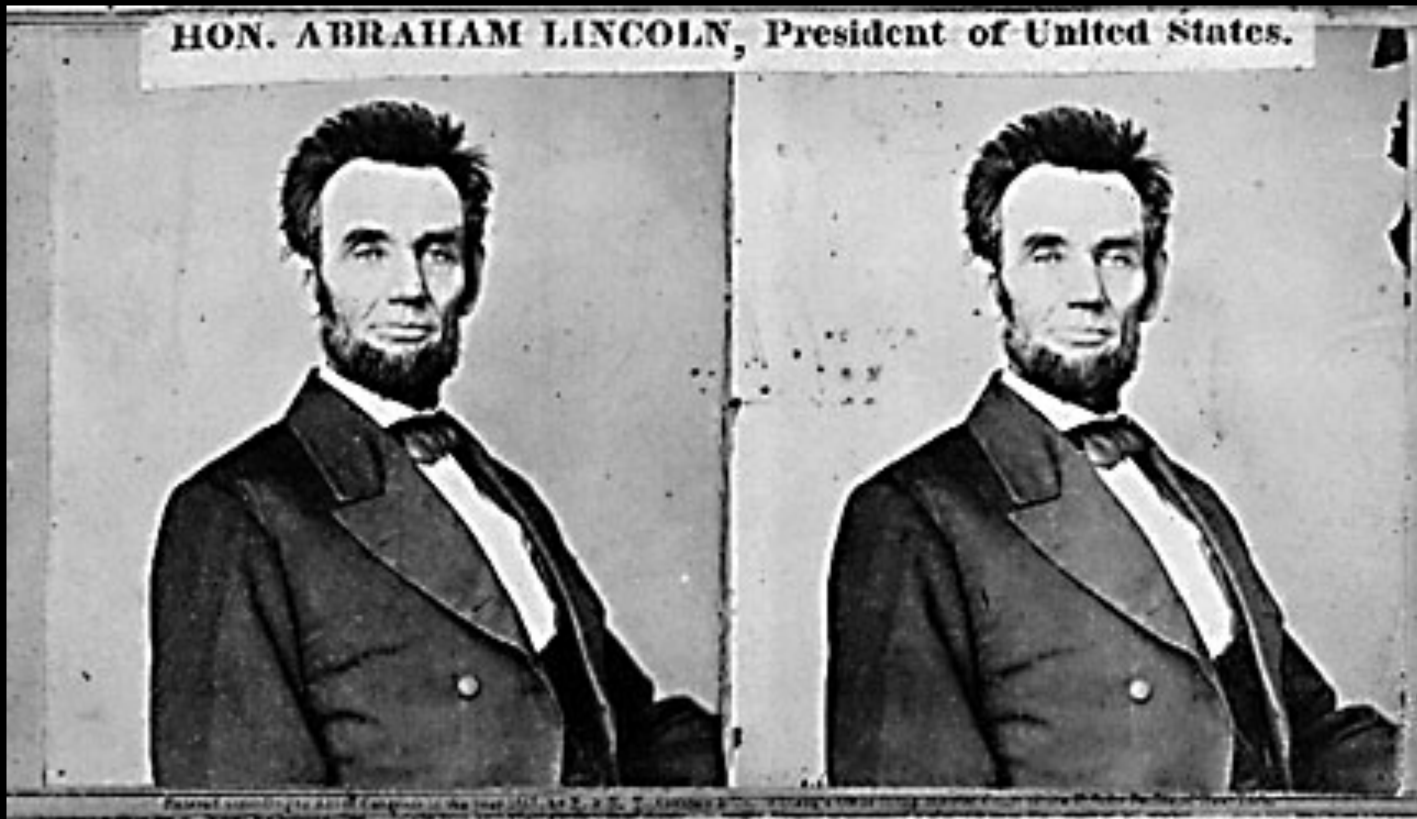
What have we learned so far?

- Projective Geometry
- Single View Modeling
- Shading Model

Project 3: Photometric Stereo

Next

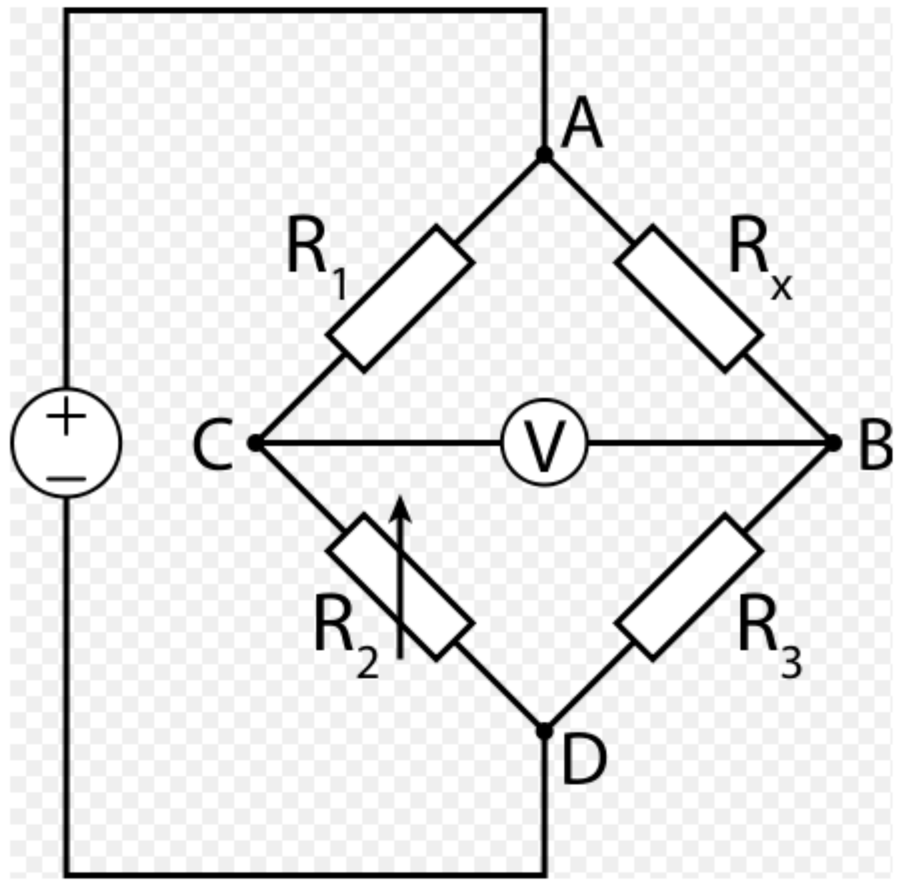
- 3D modeling from two images – Stereo


HON. ABRAHAM LINCOLN, President of United States.

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

Inventor: Sir Charles Wheatstone, 1802 - 1875

http://en.wikipedia.org/wiki/Sir_Charles_Wheatstone



Inventor: Sir Charles Wheatstone, 1802 - 1875

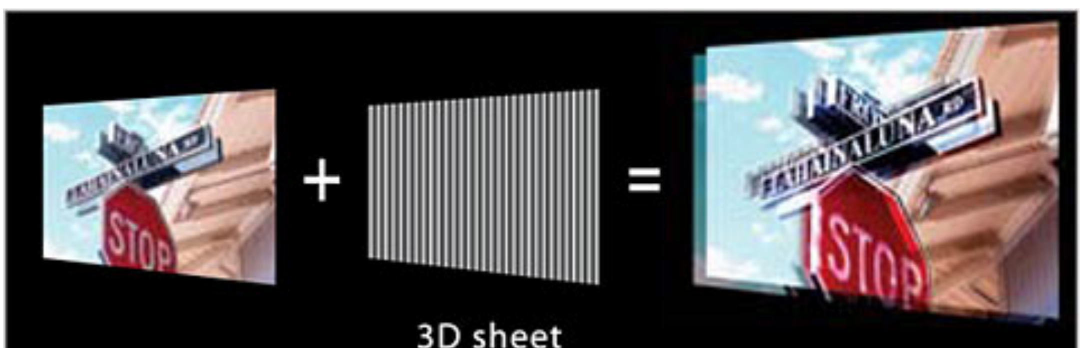
http://en.wikipedia.org/wiki/Wheatstone_bridge

Stereograms online

- UCR stereographs
  - http://www.cmp.ucr.edu/site/exhibitions/stereo/
- The Art of Stereo Photography
  - http://www.photostuff.co.uk/stereo.htm
- History of Stereo Photography
  - http://www.rpi.edu/~ruiz/stereo_history/text/historystereog.html
- Double Exposure
  - http://home.centurytel.net/s3dcor/index.html
- Stereo Photography
  - http://www.shortcourses.com/book01/chapter09.htm
- 3D Photography links
  - http://www.studyweb.com/links/5243.html
- National Stereoscopic Association
  - http://204.248.144.203/3dLibrary/welcome.html
- Books on Stereo Photography
  - http://userwww.sfsu.edu/~hl/3d.biblio.html

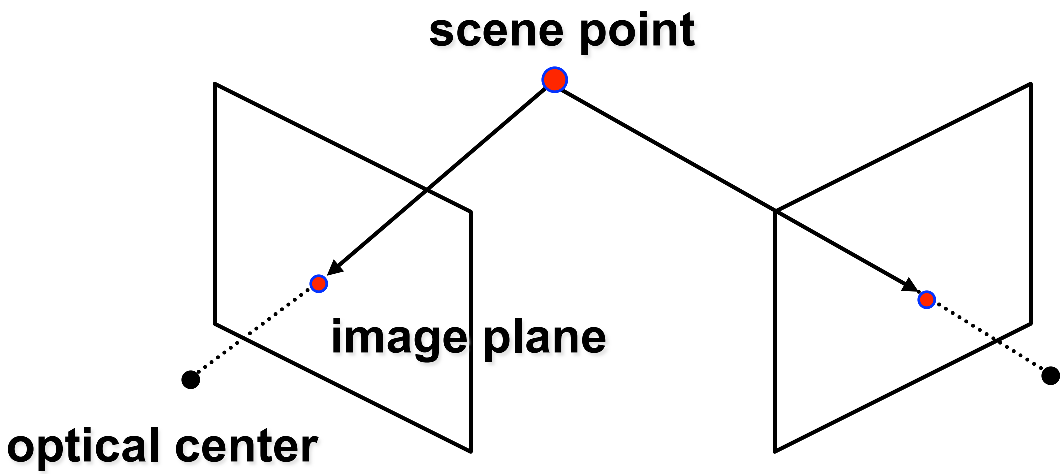
A free pair of red-blue stereo glasses can be ordered from Rainbow Symphony Inc
- http://www.rainbowsymphony.com/freestuff.html

FUJIFILM, September 23, 2008

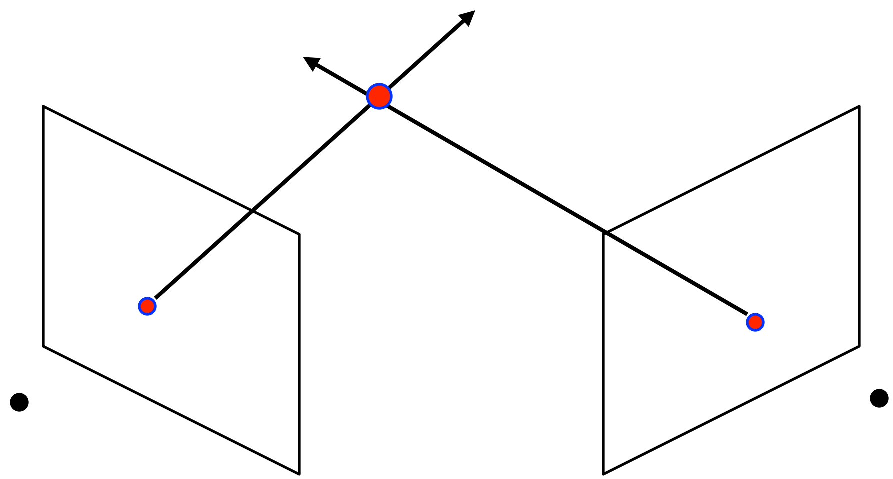


Fuji 3D printing

Stereo



Stereo

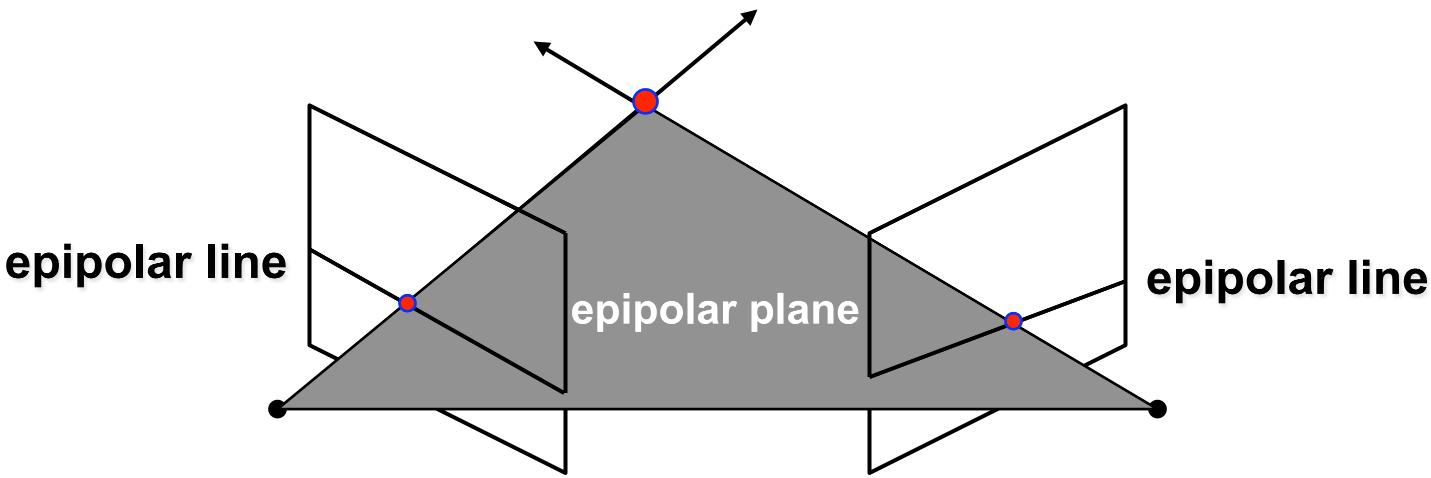


Basic Principle: Triangulation

- Gives reconstruction as intersection of two rays
- Requires
  - calibration
  - ***point correspondence***

Stereo correspondence

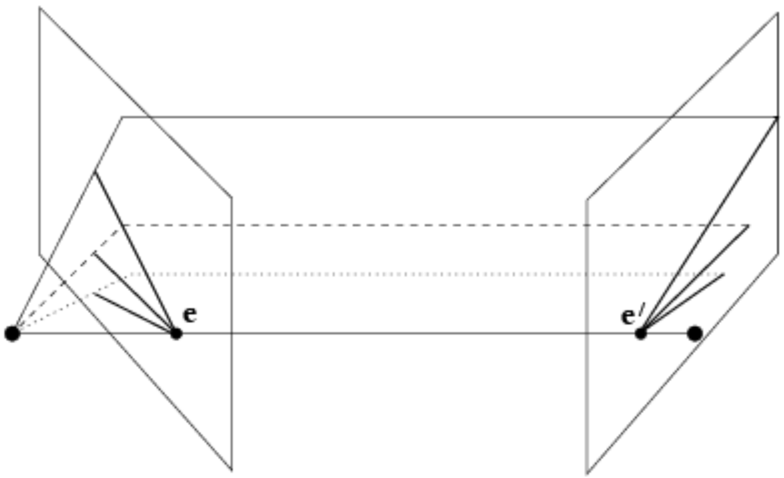
- Determine Pixel Correspondence
  - Pairs of points that correspond to same scene point

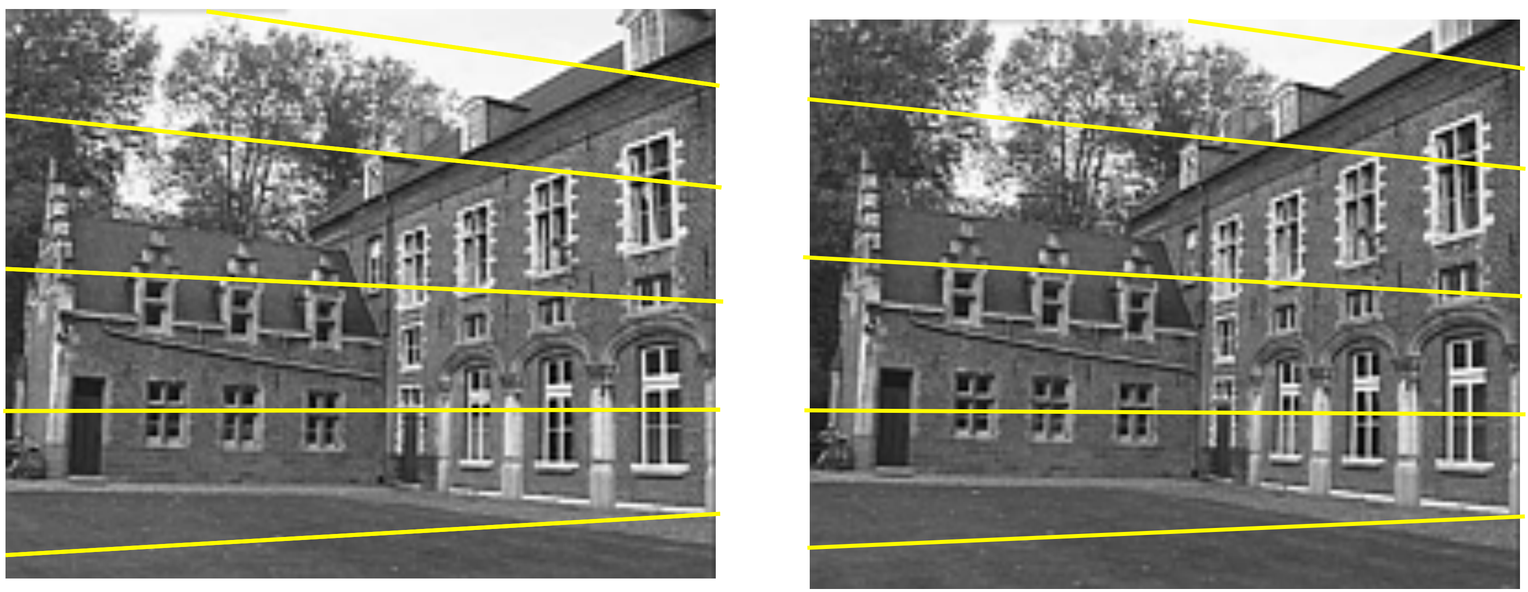


Epipolar Constraint

- Reduces correspondence problem to 1D search along *conjugate epipolar lines*
- Java demo: http://www.ai.sri.com/~luong/research/Meta3DViewer/EpipolarGeo.html

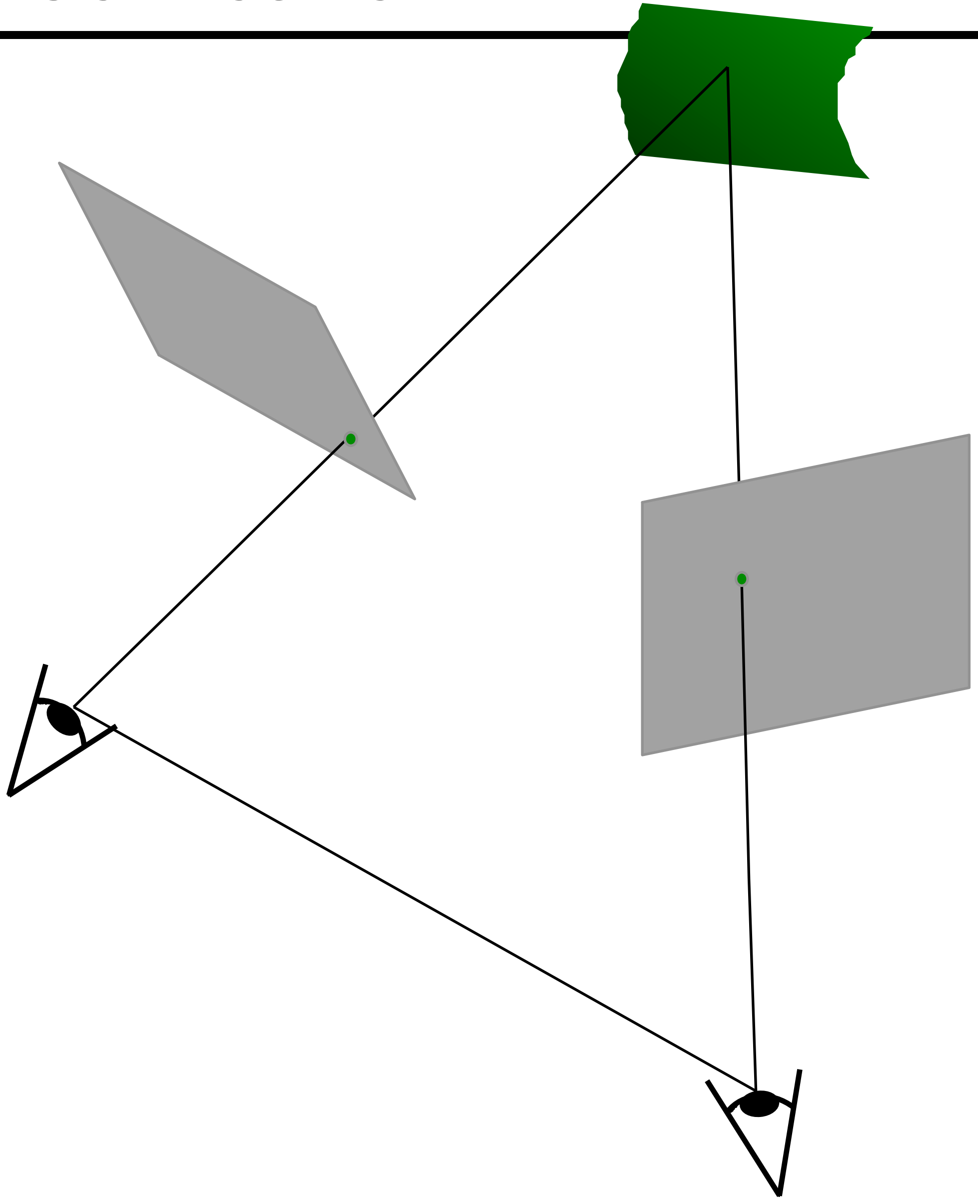
Epipolar Line Example



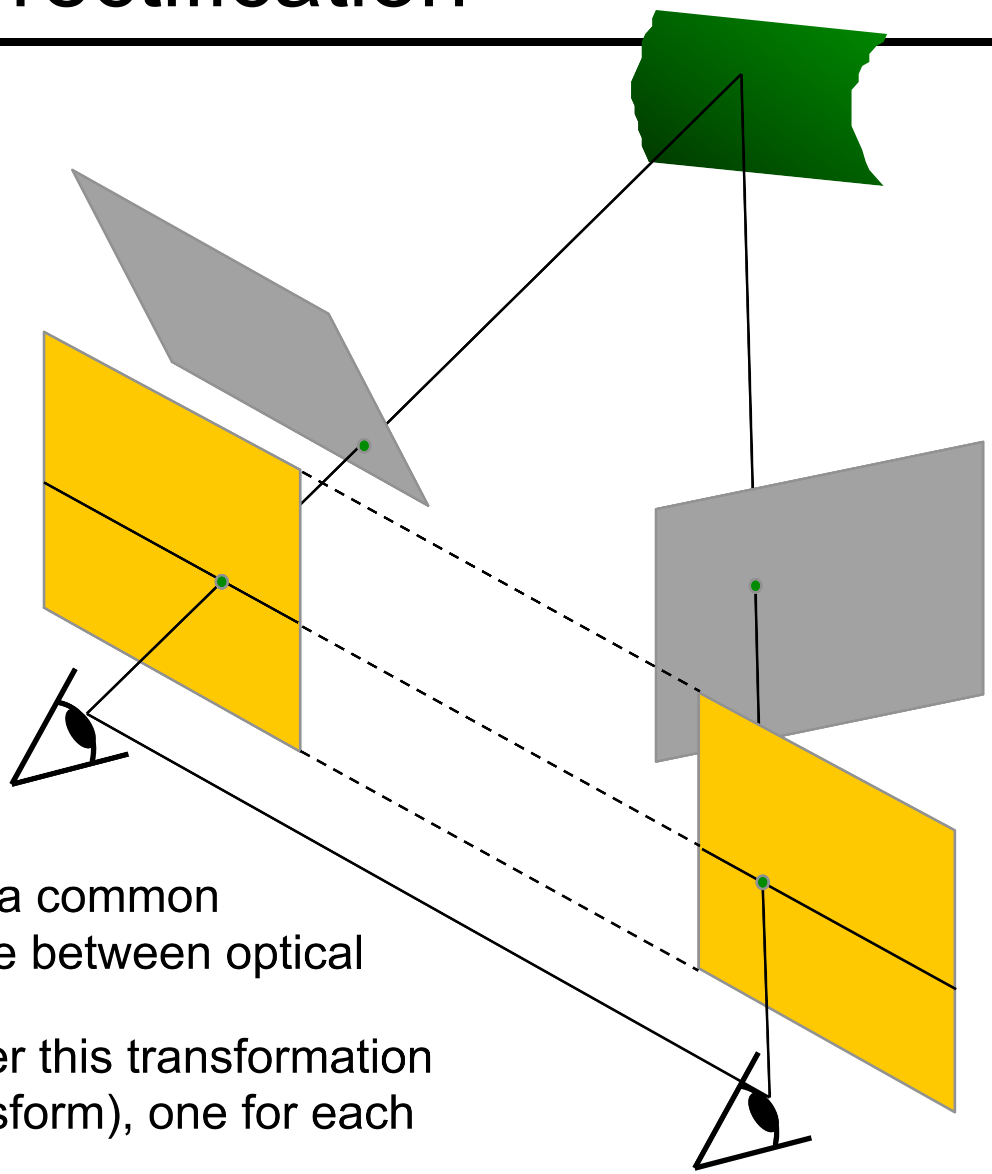


courtesy of Marc Pollefeys

Stereo image rectification



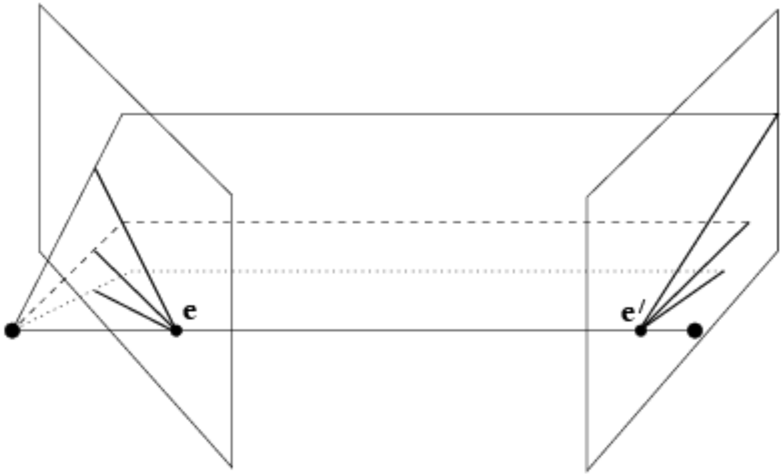
Stereo image rectification

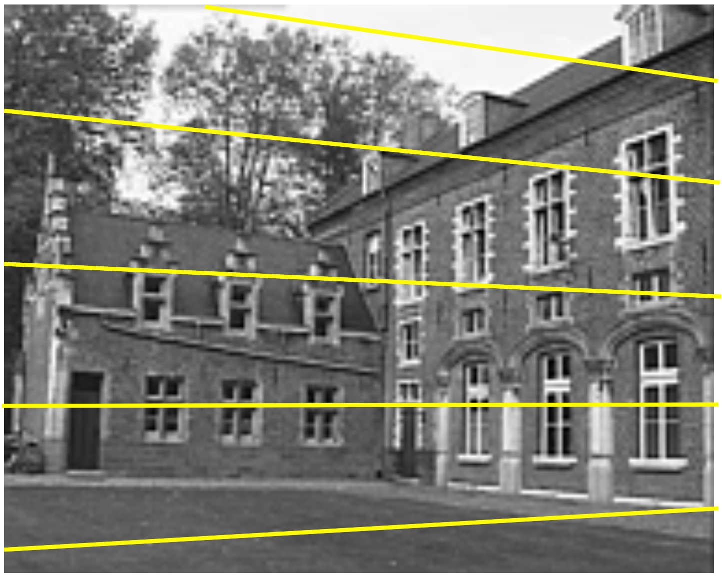


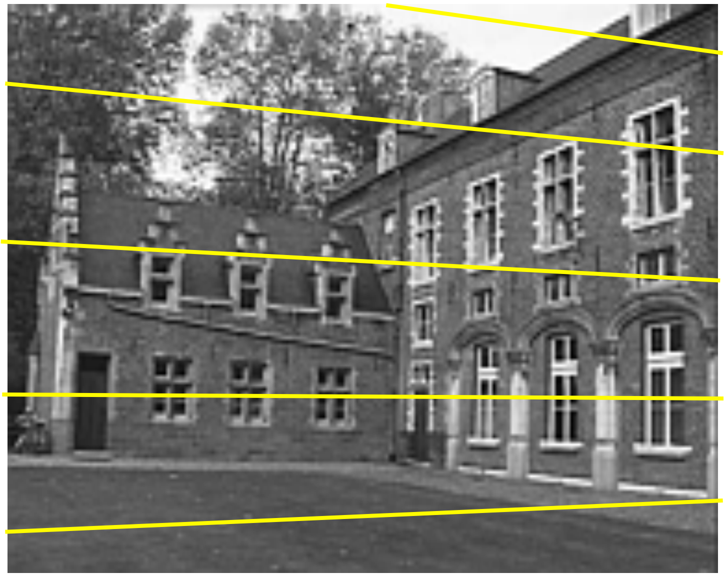
- reproject image planes onto a common
- plane parallel to the line between optical centers
- pixel motion is horizontal after this transformation
- two homographies (3x3 transform), one for each input image reprojection

➢ C. Loop and Z. Zhang. [Computing Rectifying Homographies for Stereo Vision](). IEEE Conf. Computer Vision and Pattern Recognition, 1999.

Epipolar Line Example

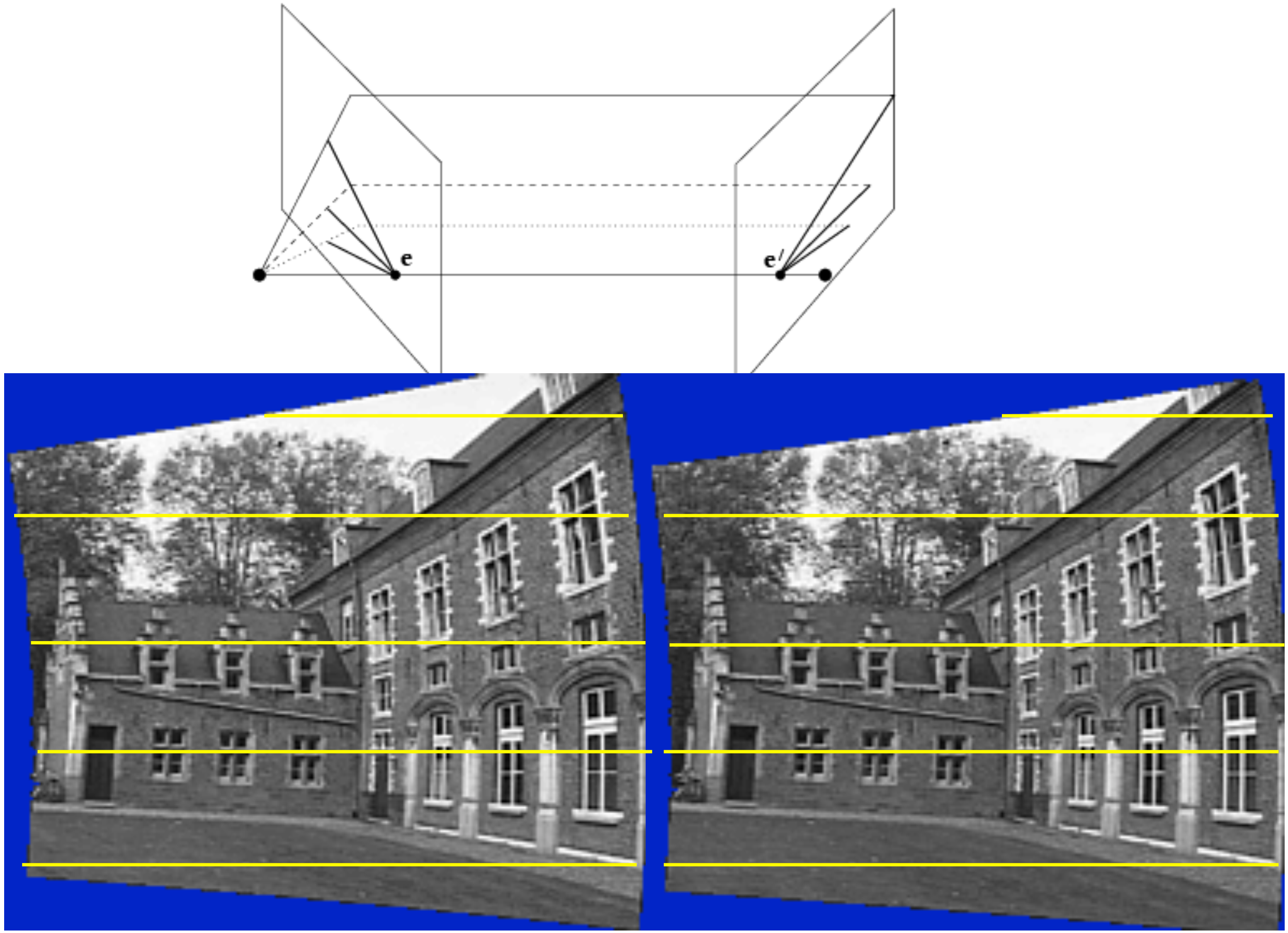






courtesy of Marc Pollefeys

Epipolar Line Example

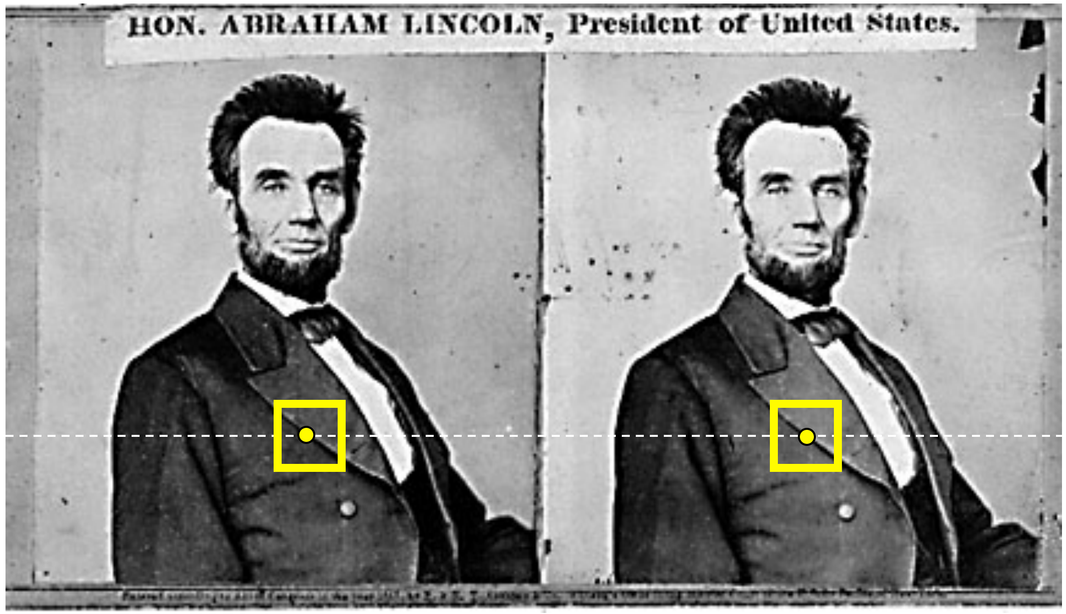


courtesy of Marc Pollefeys

Stereo matching algorithms

- Match Pixels in Conjugate Epipolar Lines
  - Assume brightness constancy
  - This is a tough problem
  - Numerous approaches
    - A good survey and evaluation: http://www.middlebury.edu/stereo/

Basic stereo algorithm



For each epipolar line

For each pixel in the left image

- compare with every pixel on same epipolar line in right image
- pick pixel with minimum match cost

Improvement: match *windows*

Basic stereo algorithm

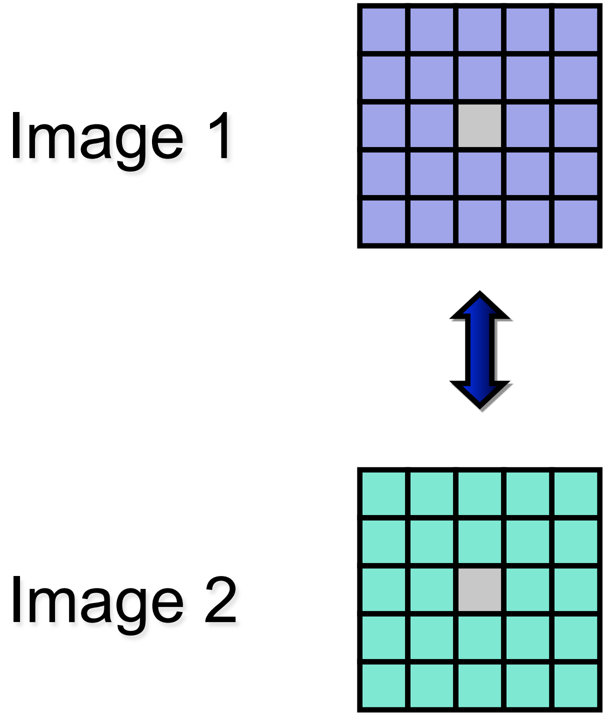
- For each pixel
  - For each disparity
    - For each pixel in window
      - » Compute difference
  - Find disparity with minimum SSD

Reverse order of loops

- For each disparity
  - For each pixel
    - For each pixel in window
      - Compute difference
- Find disparity with minimum SSD at each pixel

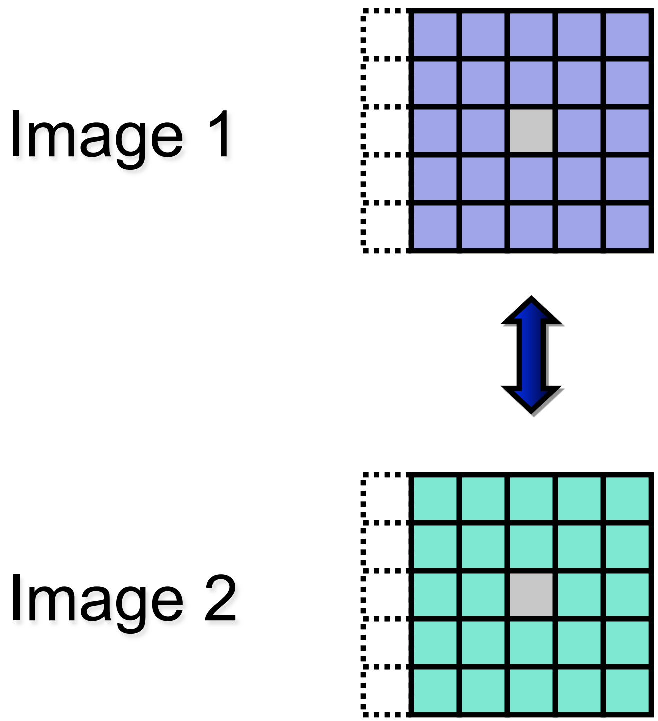
Incremental computation

- Given SSD of a window, at some disparity



Incremental computation

- Want: SSD at next location



Incremental computation

- Subtract contributions from leftmost column, add contributions from rightmost column

Image 1

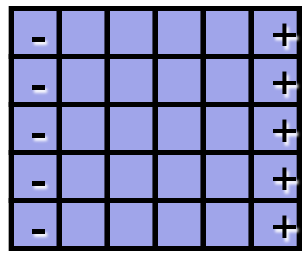
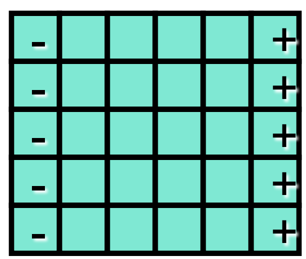


Image 2

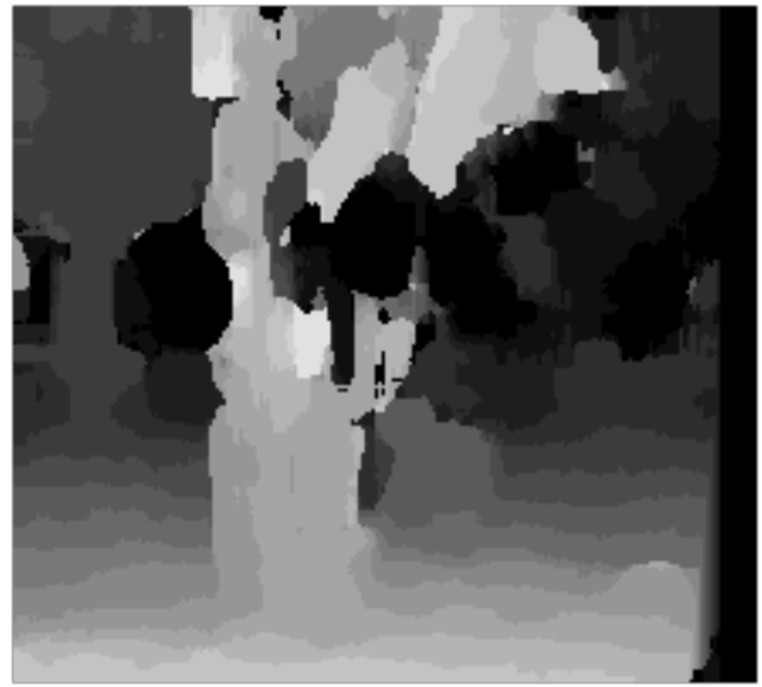


Selecting window size

- Small window: more detail, but more noise
- Large window: more robustness, less detail
- Example:

Selecting window size

3 pixel window



20 pixel window

Why?

Non-square windows

- Compromise: have a large window, but higher weight near the center
- Example: Gaussian
- Example: Shifted windows (computation cost?)

Problems with window matching

- No guarantee that the matching is one-to-one
- Hard to balance window size and smoothness