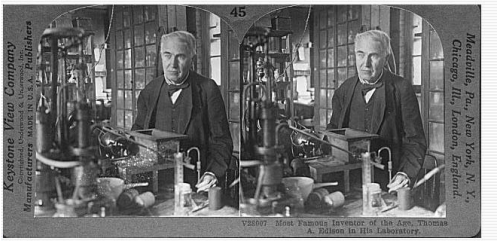
Binocular Stereo Vision

Stereo viewing geometry and the stereo correspondence problem

CS332 Visual Processing
Department of Computer Science
Wellesley College

Stereograms



Invented by Sir Charles Wheatstone, 1838

1-2

Stereo disparity

left

right

Magic-eye
“autostereograms”

1-3

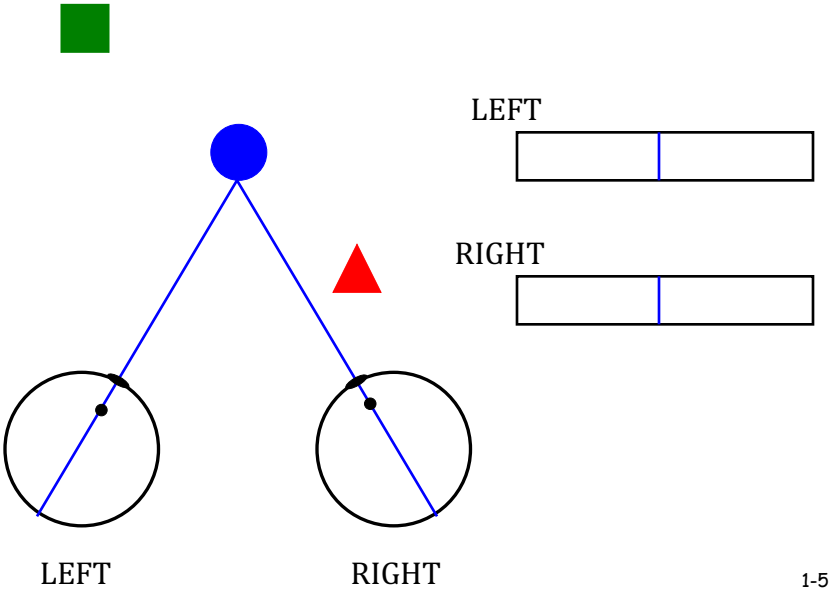
Why multiple views?

Depth is inherently ambiguous from single views

Images from Lana Lazebnik

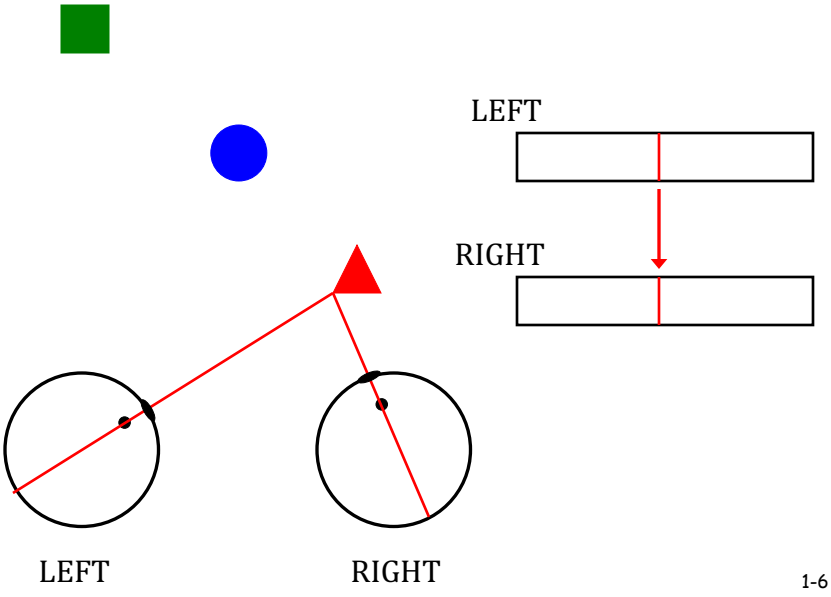
1-4

Stereo viewing geometry



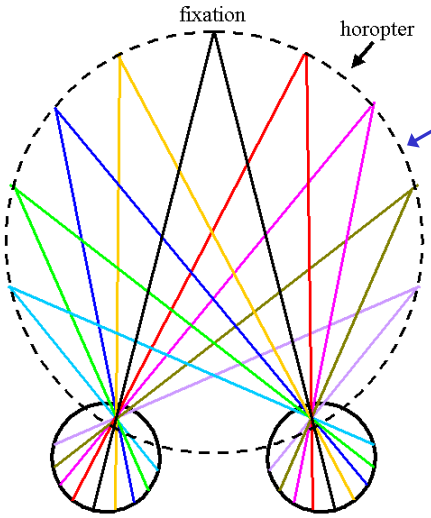
1-5

Stereo viewing geometry



1-6

Horopter



Vieth-Muller circle

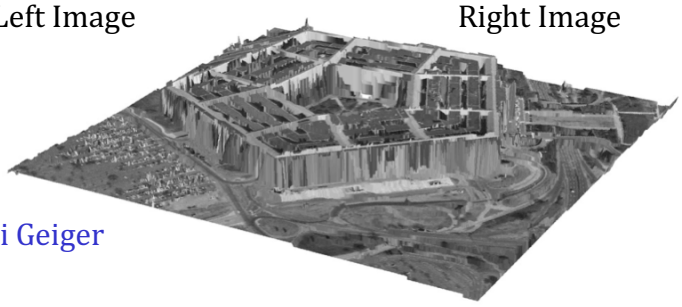
points on the horopter have zero disparity

1-7

Results of stereo processing

Left Image

Right Image



Davi Geiger

1-8

Steps of the stereo process

left

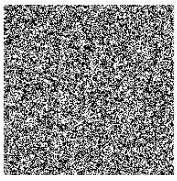
right

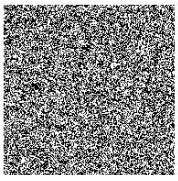
- extract features from the left and right images, whose stereo disparity will be measured
- match the left and right image features and measure their disparity in position

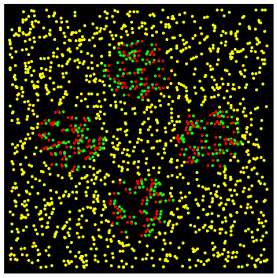
  "stereo correspondence problem"
- use stereo disparity to compute depth

1-9

Random-dot stereograms







- Bela Julesz, 1971
- stereo system can function independently
- we can match "simple" features
- highlight the ***ambiguity*** of the matching process

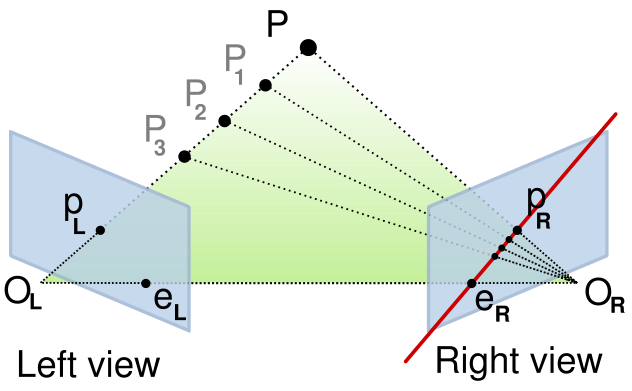
1-10

Constraints on stereo correspondence

- Uniqueness
  - each feature in the left image matches with only one feature in the right (and vice versa…)
- Similarity
  - matching features appear "similar" in the two images
- Continuity
  - nearby image features have similar disparities
- Epipolar constraint
  - simple version: matching features have similar vertical positions, but…

1-11

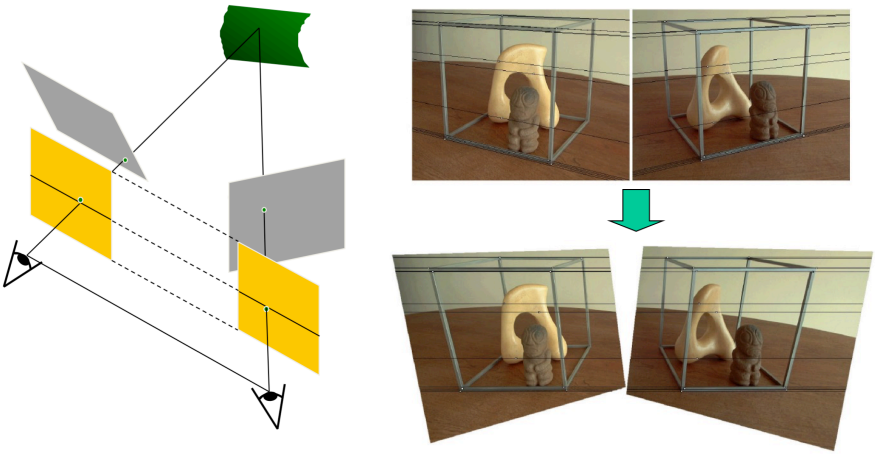
Epipolar constraint



Possible matching candidates for p_L lie along a line in the right image (the epipolar line…)

1-12

Epipolar constraint

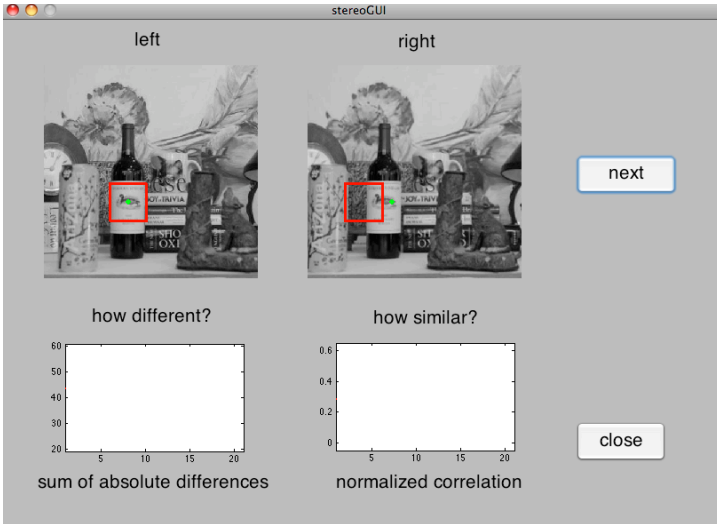


Stereo viewing geometry →

Transform image so that corresponding features lie on the same horizontal lines in left/right images

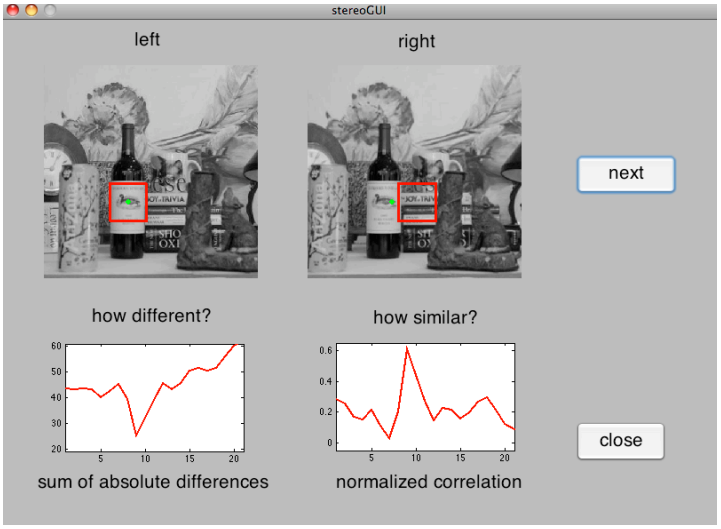
1-13

Solving the stereo correspondence problem



1-14

Solving the stereo correspondence problem



1-15

Measuring goodness of match between patches

(1) sum of absolute differences

$$(1/n) \sum_{\text{patch}} | p_{\text{left}} - p_{\text{right}} |$$

optional: divide by n = number of pixels in patch

(2) normalized correlation

$$(1/n) \sum_{\text{patch}} \frac{(p_{\text{left}} - \overline{p_{\text{left}}})\,(p_{\text{right}} - \overline{p_{\text{right}}})}{\sigma_{p_{\text{left}}}\,\sigma_{p_{\text{right}}}}$$

$\overline{p}$ = average of values within patch

σ = standard deviation of values within patch

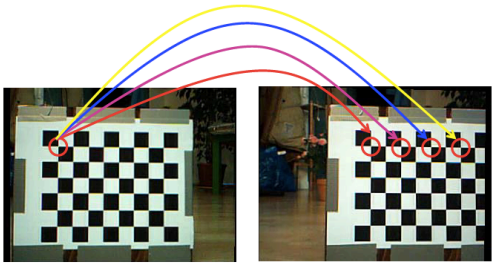
1-16

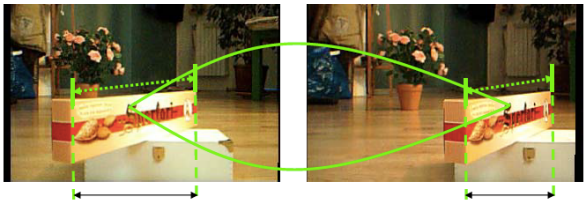
Region-based stereo matching algorithm

for each row r
  for each column c
    let p_{left} be a square patch centered on (r,c) in the left image
      initialize best match score m_{best} to ∞
      initialize best disparity d_{best}
      for each disparity d from $-d_{range}$ to $+d_{range}$
        let p_{right} be a square patch centered on (r,c+d) in the right image
        compute the match score m between p_{left} and p_{right}
                (sum of absolute differences) (normalized correlation)
        if ($m < m_{best}$), assign $m_{best} = m$ and $d_{best} = d$
      record d_{best} in the disparity map at (r,c)

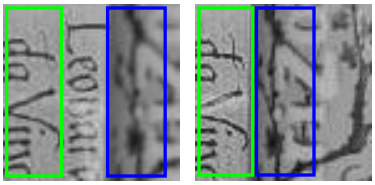
How are the assumptions used??

1-17

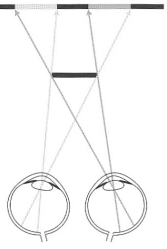




The real world works against us sometimes…



left right

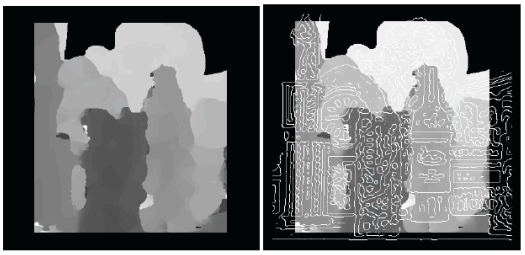


1-18

Example: Region-based stereo matching, using filtered images and sum of absolute differences

(from Carolyn Kim '13)

(a)



(results before improvements)

1-19