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

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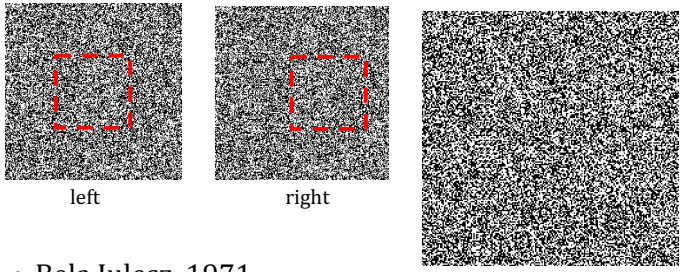
Random-dot stereograms



left right

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

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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…

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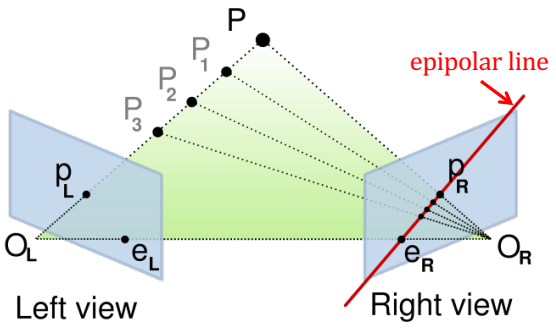
Epipolar constraint



possible matching candidates for p_L in the left image lie along a line in the right image - the *epipolar line*

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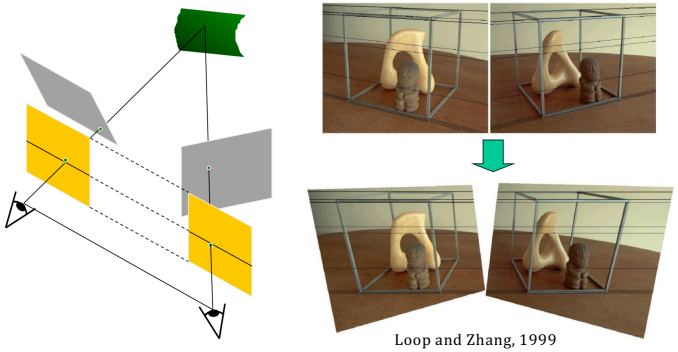
Epipolar constraint



Loop and Zhang, 1999

stereo camera calibration: given known viewing geometry, transform left/right images so that corresponding features lie on the same horizontal lines

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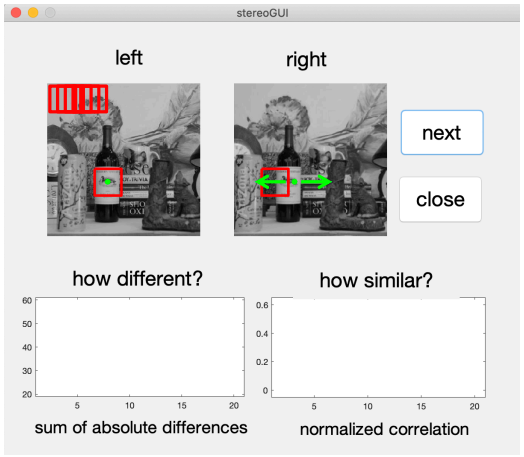
Solving the stereo correspondence problem



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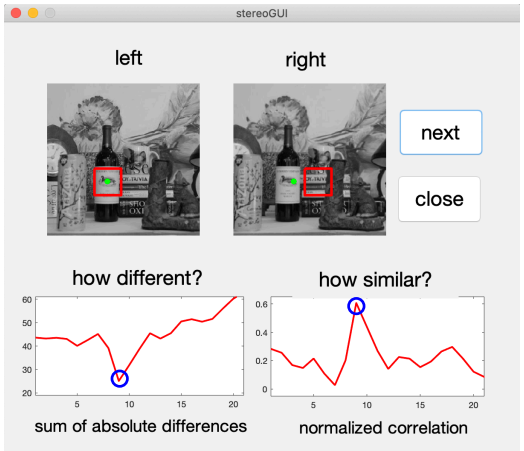
Solving the stereo correspondence problem



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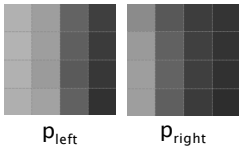
Measuring goodness of match between patches

(1) sum of absolute differences

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



(2) normalized correlation

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

optional: divide by n = number of pixels in patch

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

σ = standard deviation of values within patch

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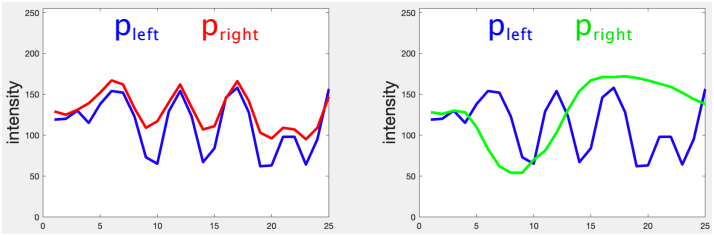
Computing normalized correlation



How well correlated is the pattern of intensity variation in a patch from the left image, p_{left} , and the pattern of intensity variation in a patch from the right image, p_{right} or p_{right} ?

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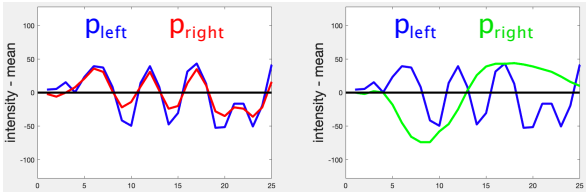
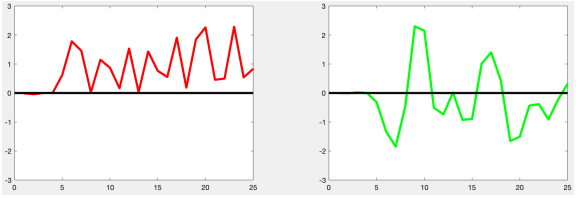
Computing normalized correlation

(1) for each patch, subtract the mean intensity



(2) multiply two results, element-by-element, and divide by standard deviations



normalized correlation (sum of result)

23.5

-4.1

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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 constraints used??

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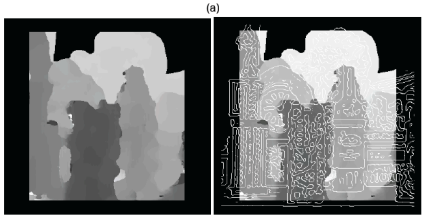
Example: Region-based stereo matching, using filtered images and sum of absolute differences

(from Carolyn Kim '13)

(a)

(results before improvements)



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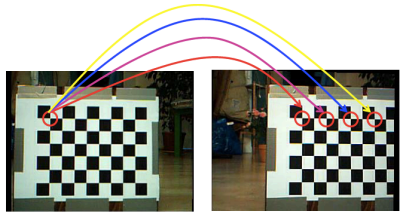
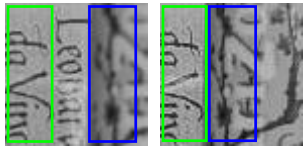
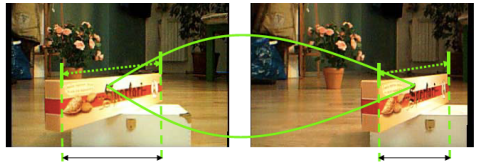
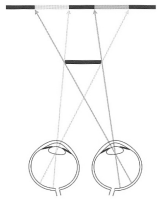
The real world works against us sometimes…





left right





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