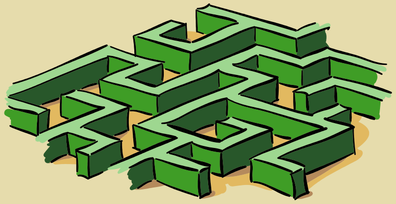
Binocular stereo

- Given a calibrated binocular stereo pair, produce a depth image

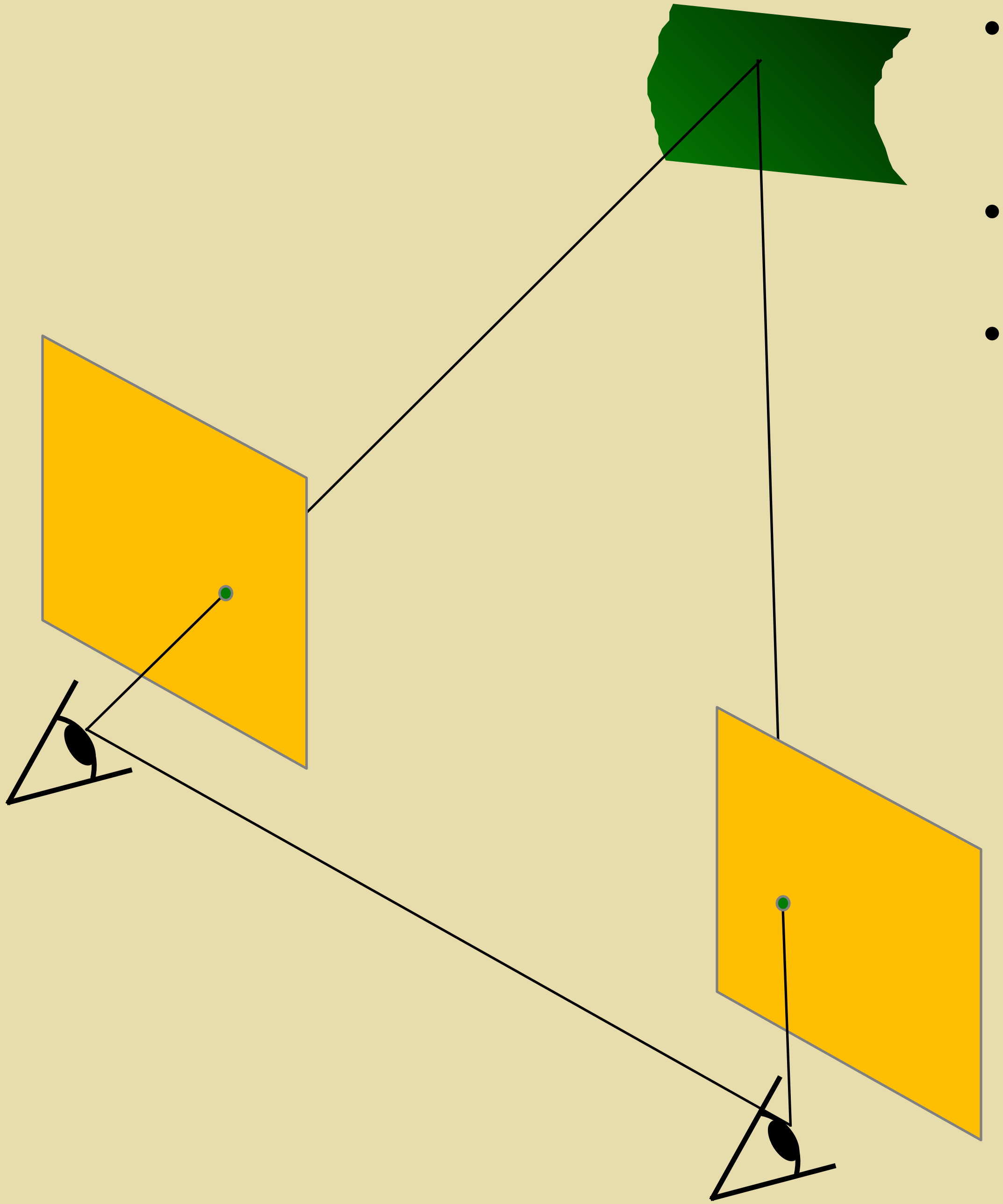
image 1

image 2

Dense depth map



Simplest Case: Parallel images



- Image planes of cameras are parallel to each other and to the baseline
- Camera centers are at same height
- Focal lengths are the same

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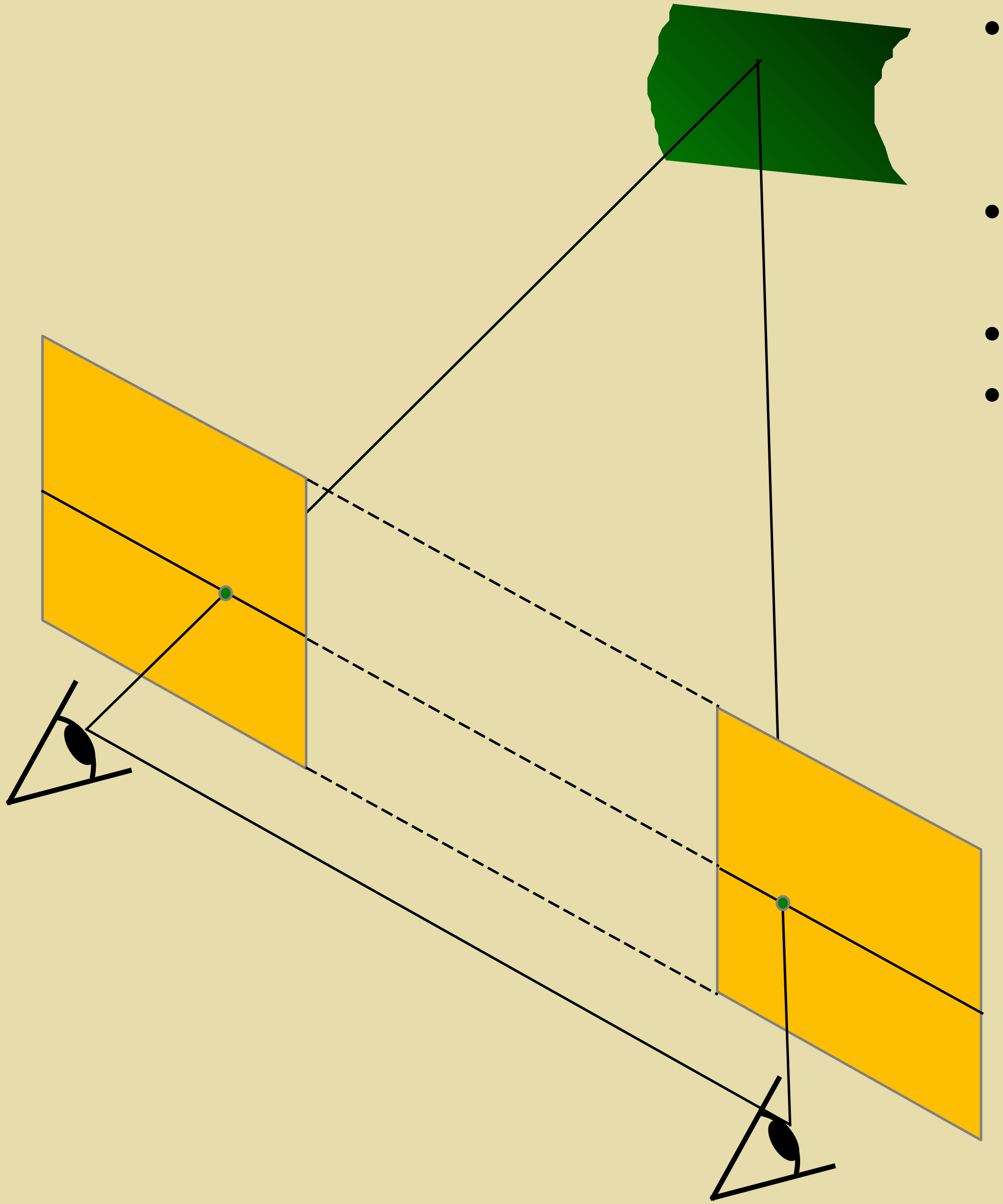
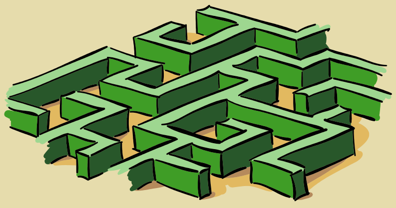
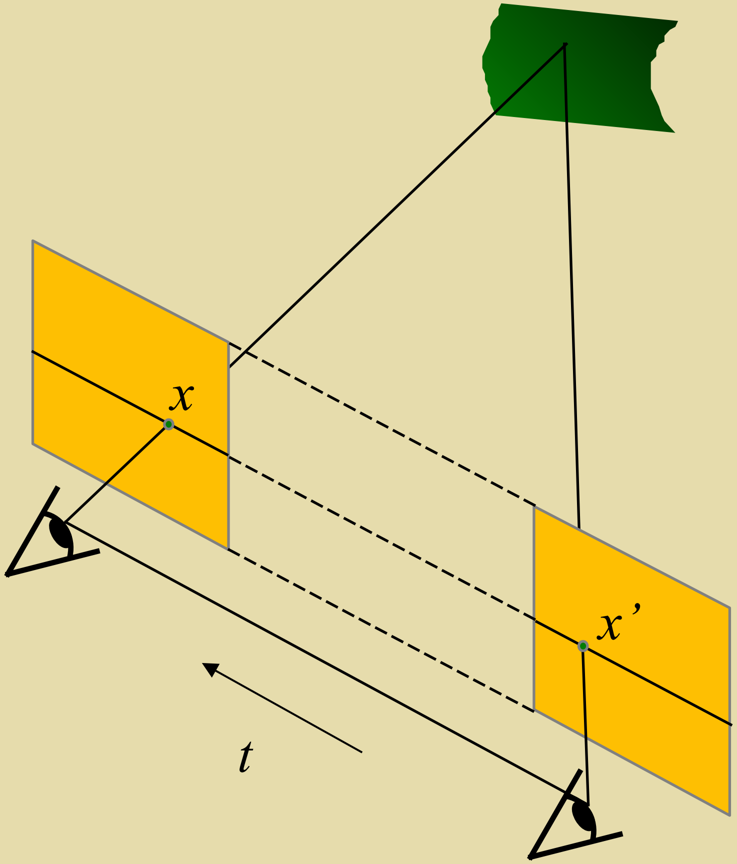


- Image planes of cameras are parallel to each other and to the baseline
- Camera centers are at same height
- Focal lengths are the same
- Then, epipolar lines fall along the horizontal scan lines of the images



Essential matrix for parallel images

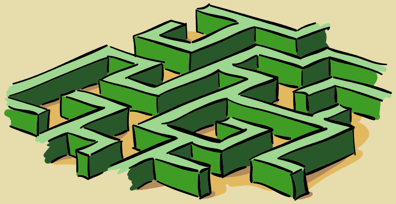


Epipolar constraint:

$$x^T E x' = 0, \quad E = [t_\times]R$$

$$R = I \qquad t = (T, 0, 0)$$

$$E = [t_\times]R = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -T \\ 0 & T & 0 \end{bmatrix}$$



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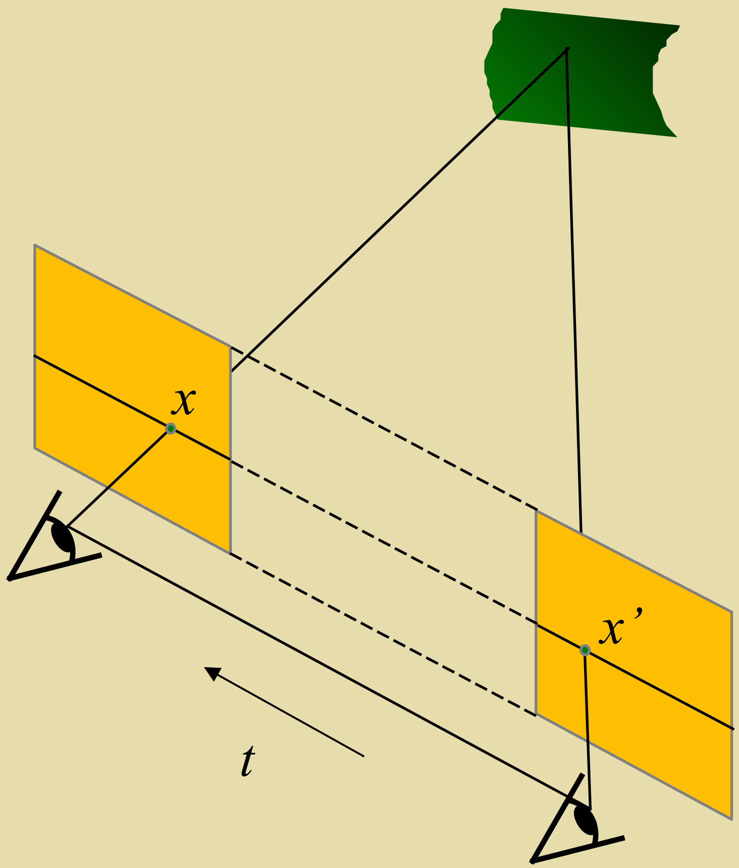

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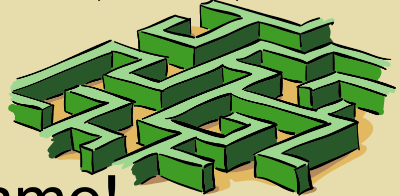
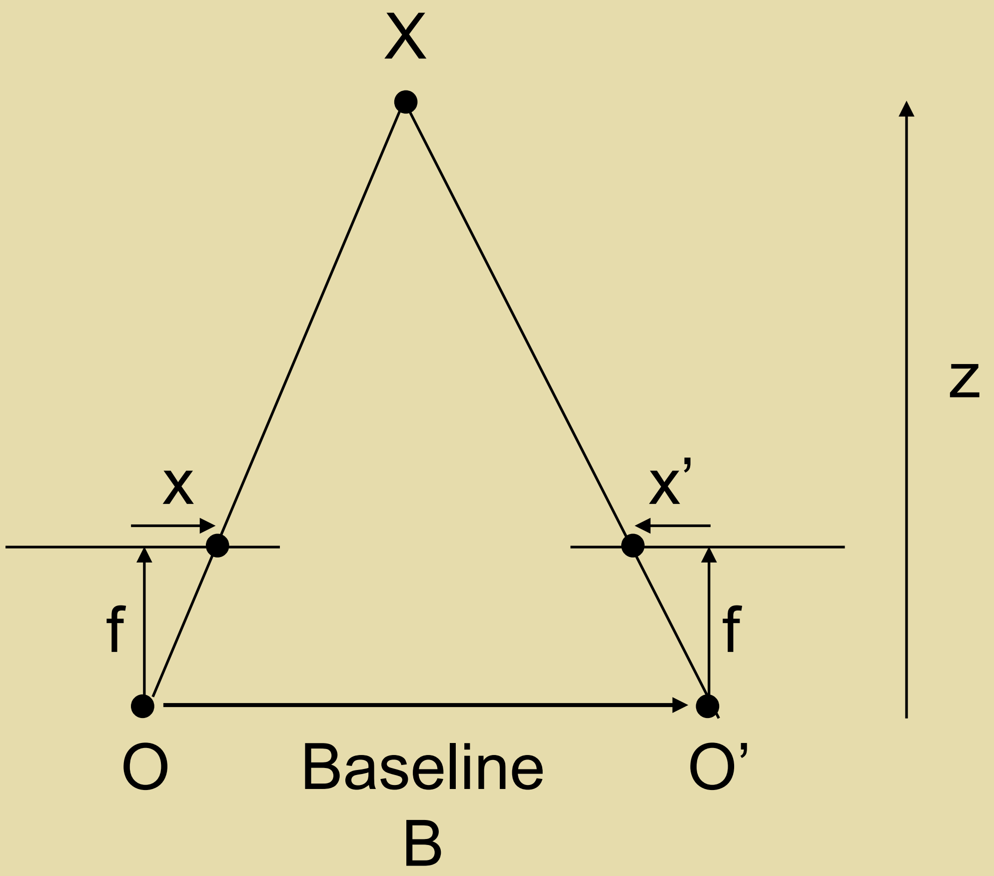
$$\begin{pmatrix} u & v & 1 \end{pmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -T \\ 0 & T & 0 \end{bmatrix} \begin{pmatrix} u' \\ v' \\ 1 \end{pmatrix} = 0 \qquad \begin{pmatrix} u & v & 1 \end{pmatrix} \begin{pmatrix} 0 \\ -T \\ Tv' \end{pmatrix} = 0 \qquad Tv = Tv'$$



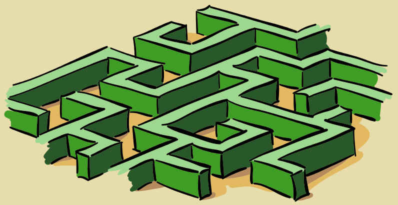
The y-coordinates of corresponding points are the same!

Depth from disparity

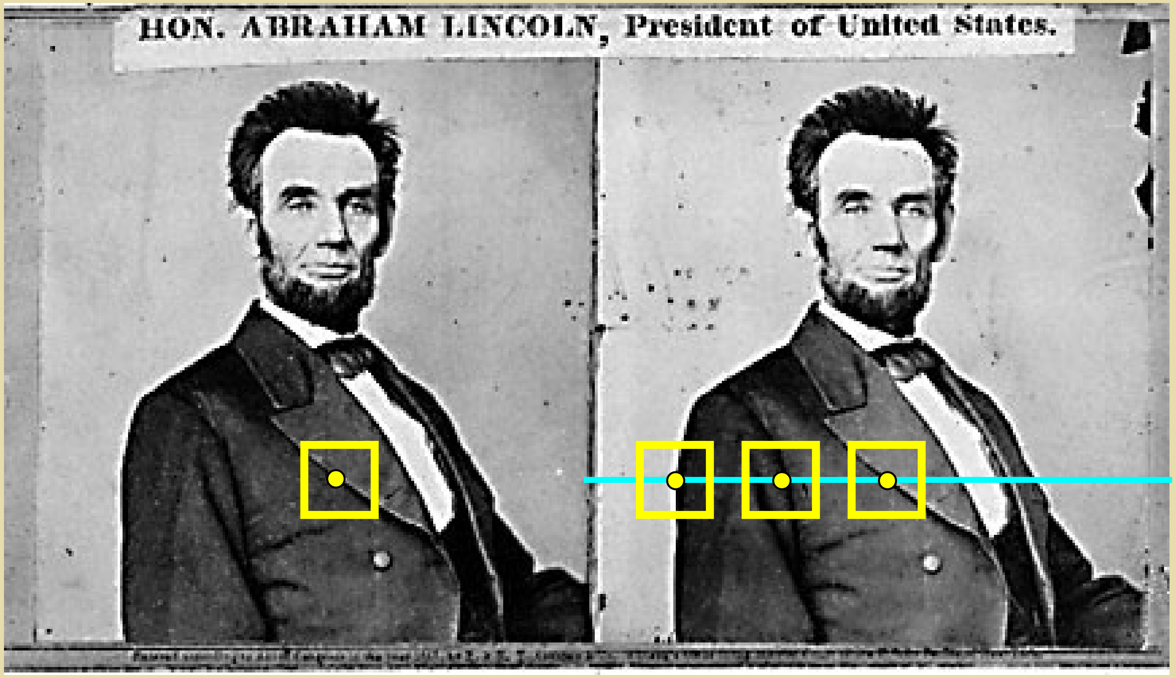


$$disparity = x - x' = \frac{B \cdot f}{z}$$

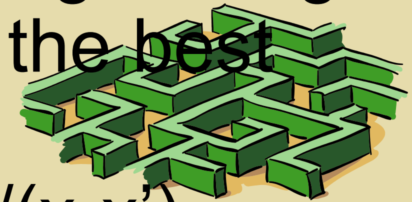
Disparity is inversely proportional to depth!



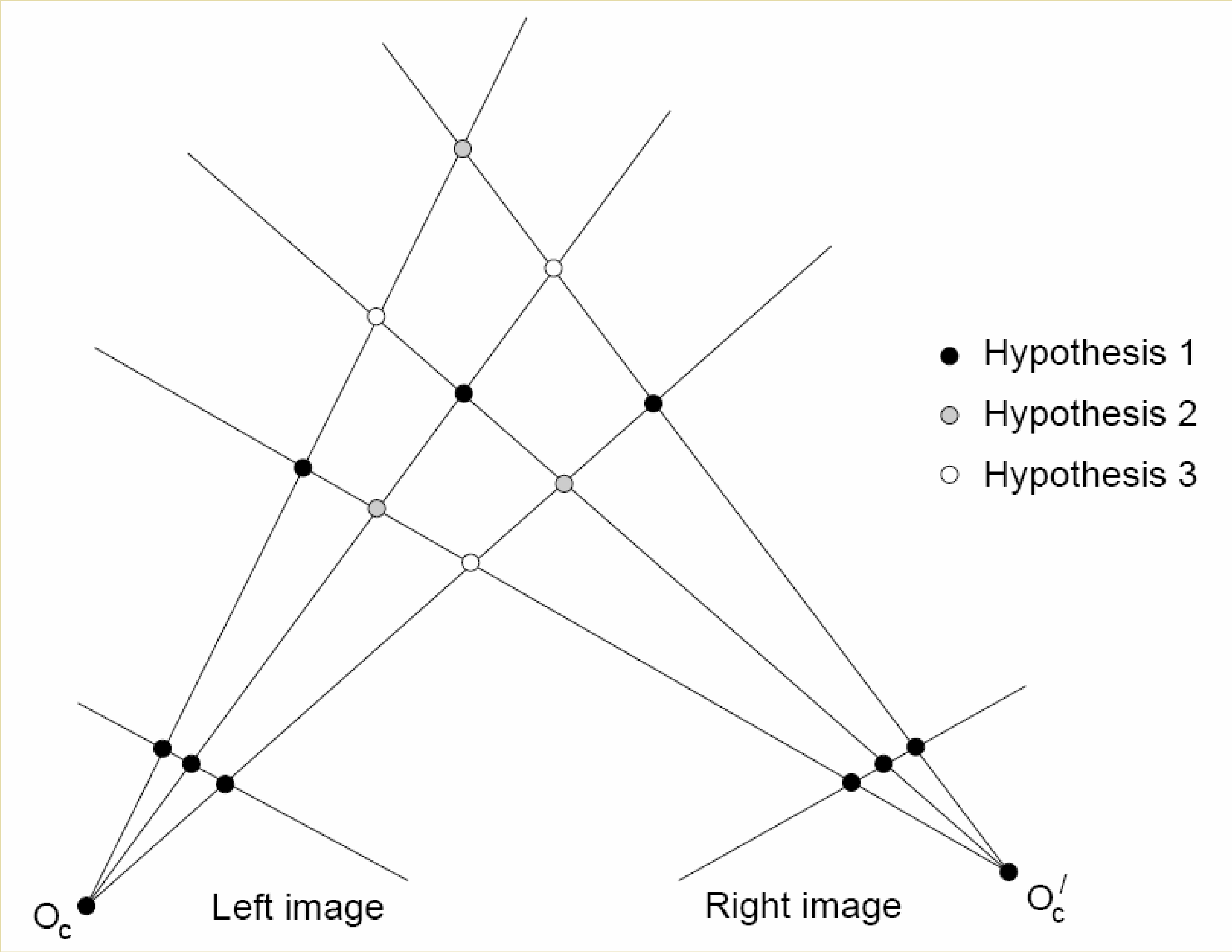
Basic stereo matching algorithm



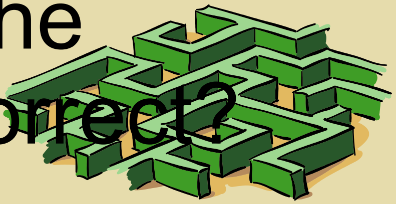
- If necessary, rectify the two stereo images to transform epipolar lines into scanlines
- For each pixel x in the first image
  - Find corresponding epipolar scanline in the right image
  - Examine all pixels on the scanline and pick the best match x’
  - Compute disparity x-x’ and set depth(x) = 1/(x-x’)



Correspondence problem

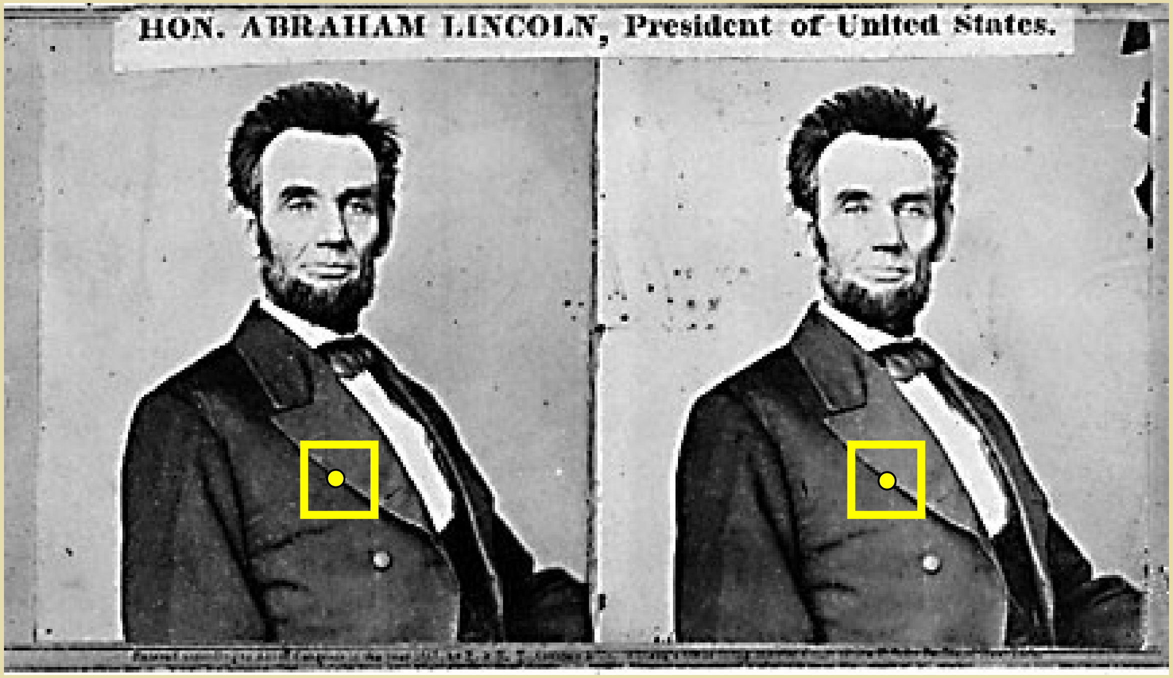


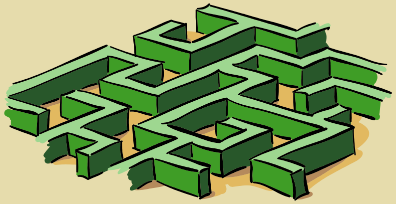
- Multiple matching hypotheses satisfy the epipolar constraint, but which one is correct?



Correspondence problem

- Let's make some assumptions to simplify the matching problem
  - The baseline is relatively small (compared to the depth of scene points)
  - Then most scene points are visible in both views
  - Also, matching regions are similar in appearance





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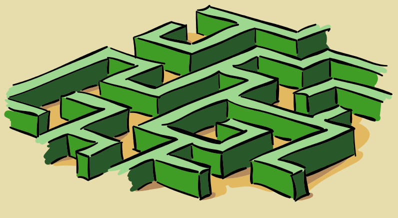
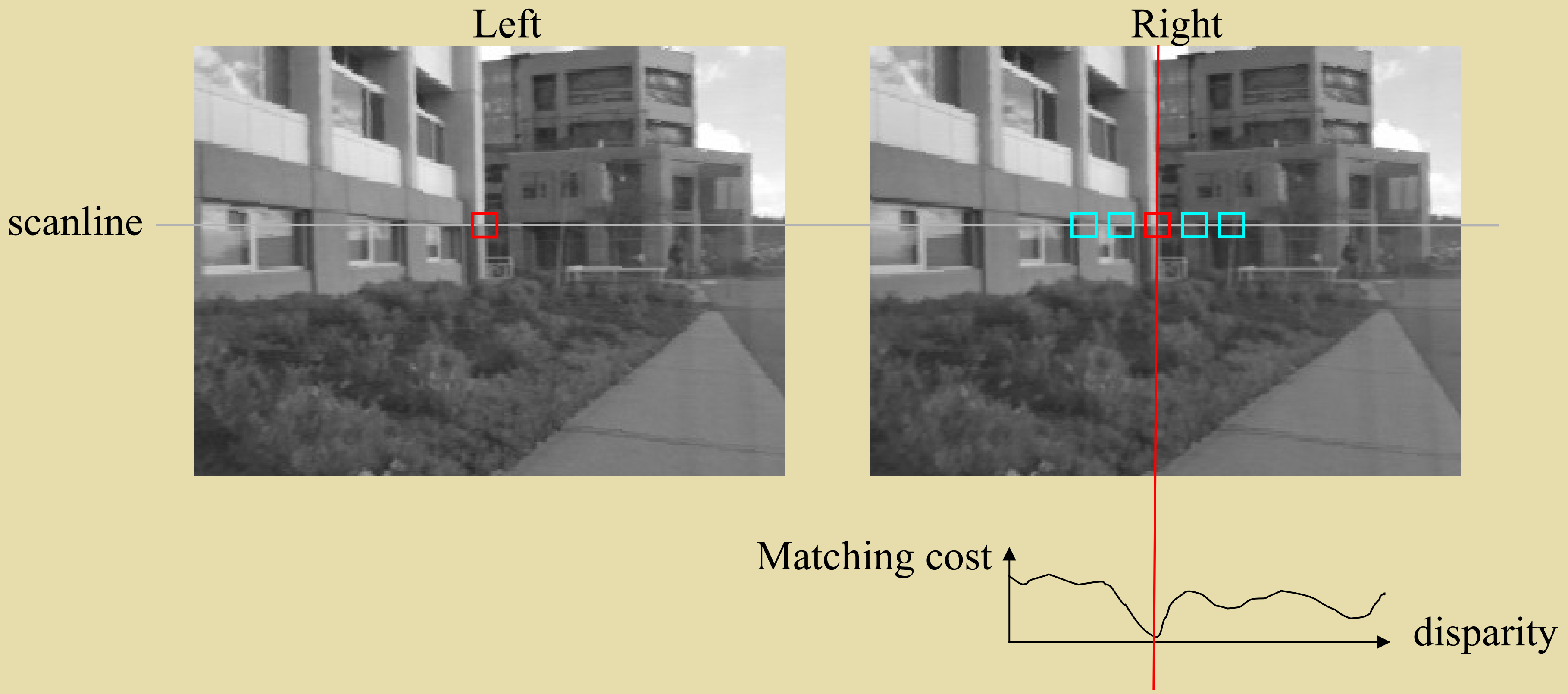
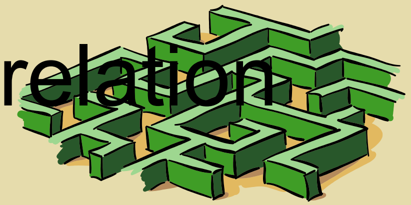


Correspondence search with similarity constraint



- Slide a window along the right scanline and compare contents of that window with the reference window in the left image
- Matching cost: SSD or normalized correlation



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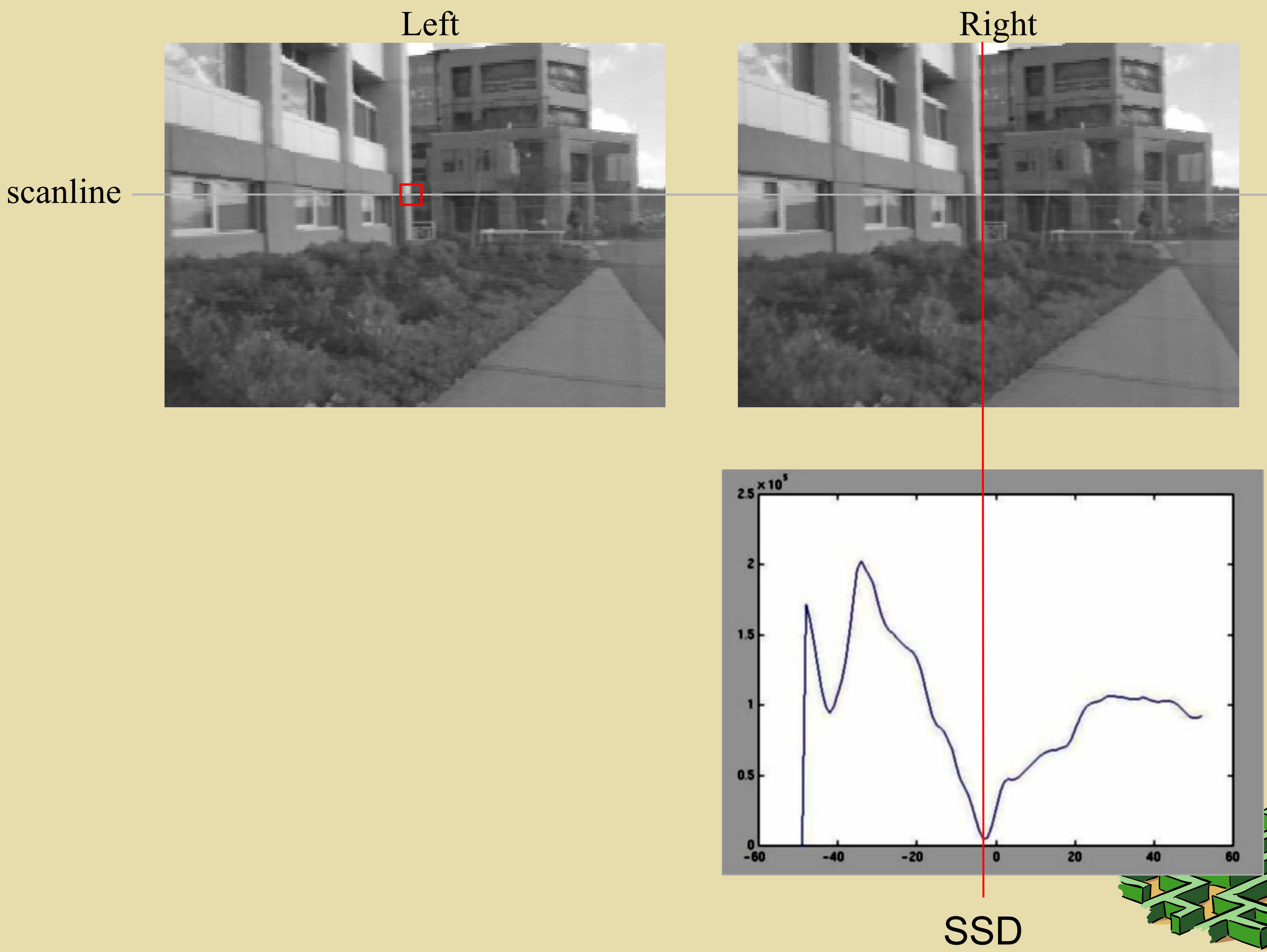

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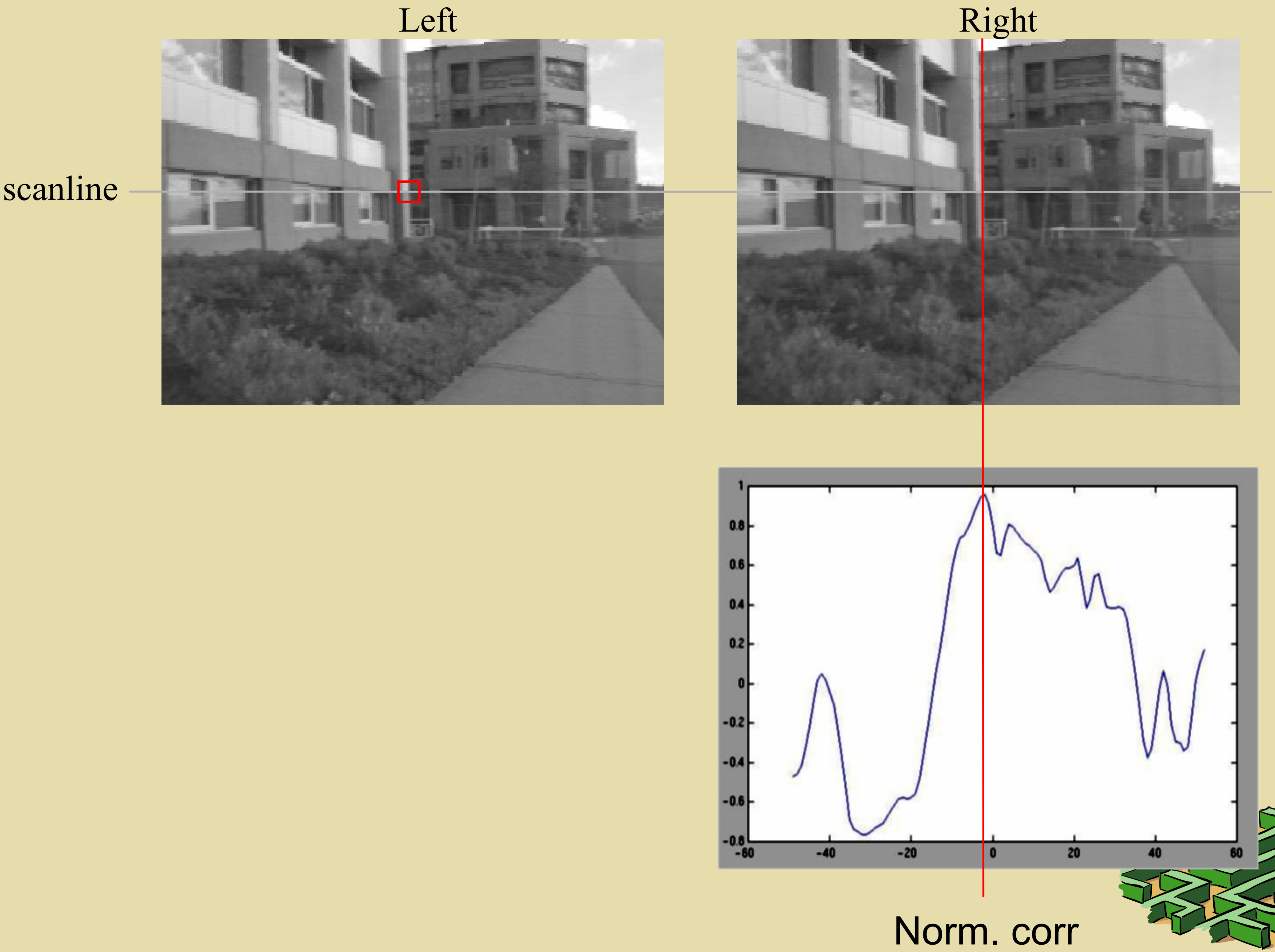
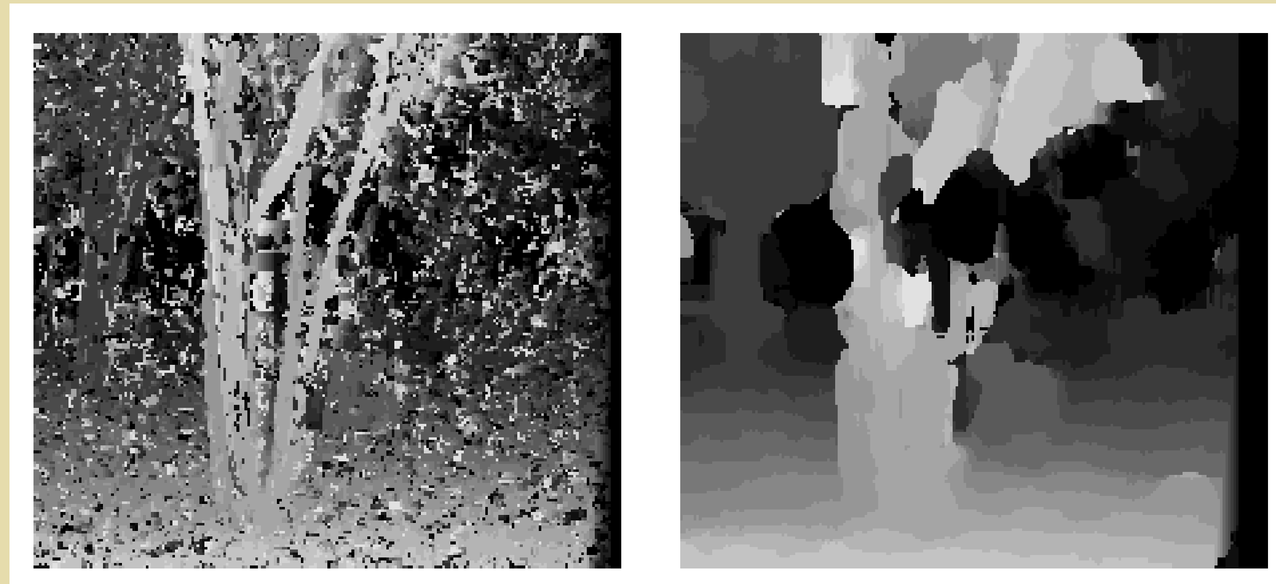


Effect of window size

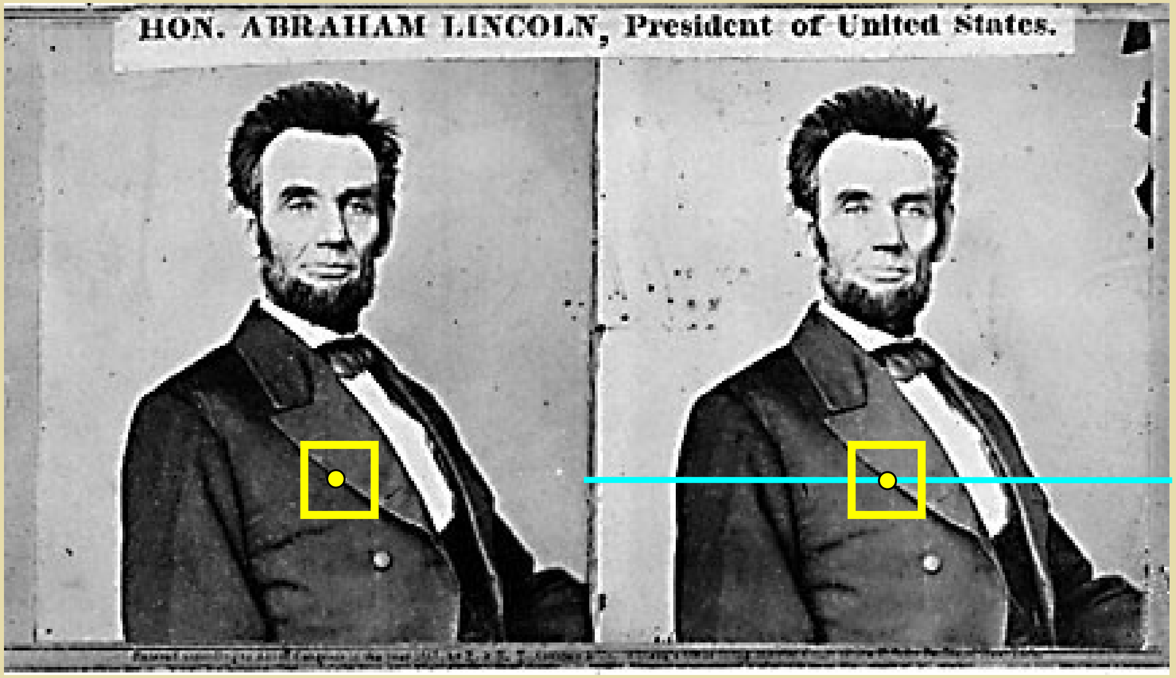


W = 3 W = 20

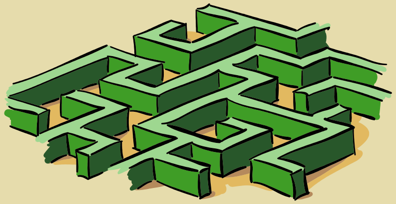
- Smaller window
  - + More detail
  - • More noise

- Larger window
  - + Smoother disparity maps
  - • Less detail

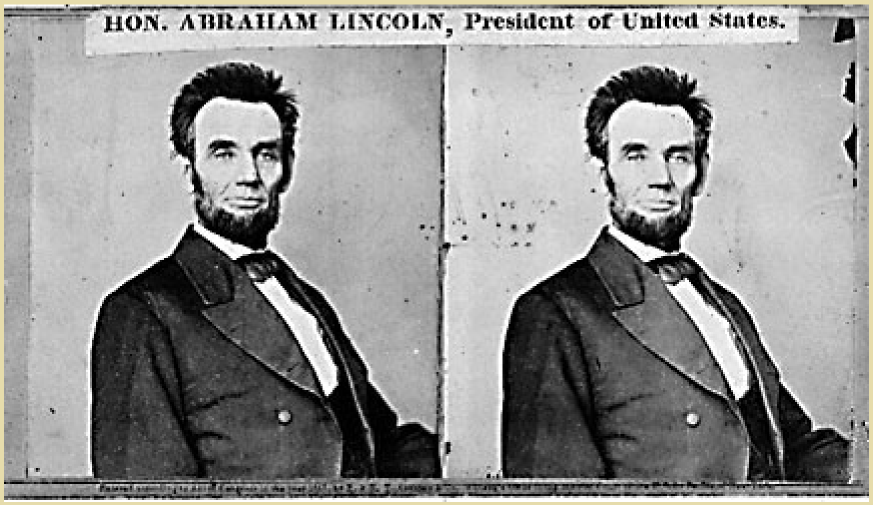
The similarity constraint



- Corresponding regions in two images should be similar in appearance
- …and non-corresponding regions should be different
- When will the similarity constraint fail?



Limitations of similarity constraint



Textureless surfaces

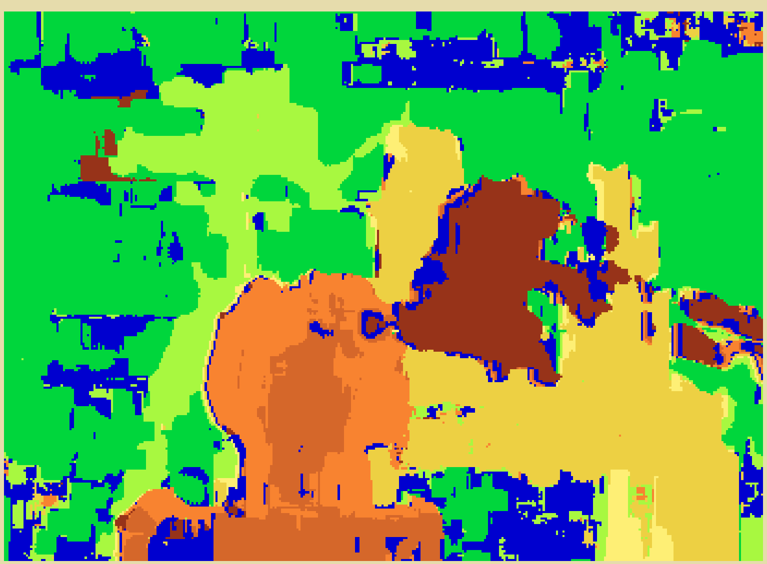
Occlusions, repetition

Non-Lambertian surfaces, specularities

Results with window search

Data

Window-based matching



Ground truth

Non-local constraints

- Uniqueness
  - For any point in one image, there should be at most one matching point in the other image