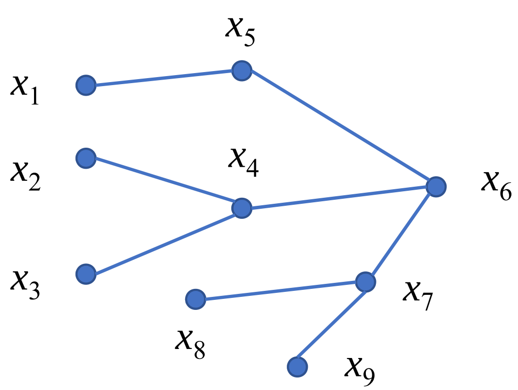
(1) DP can be extended to perform inference

on any graph which does not have closed loops



Key idea: decompose

The inference into steps which can be computed independently

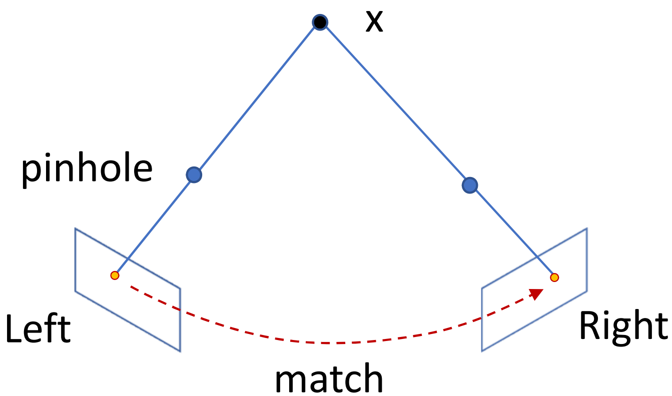
(2) DP can be extended to some graphs

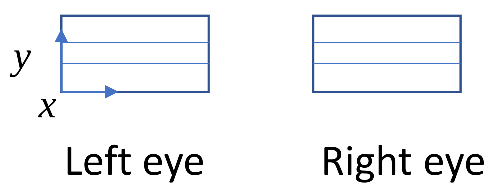
with closed loops – junction trees

(3) DP can be modified to compute other quantities

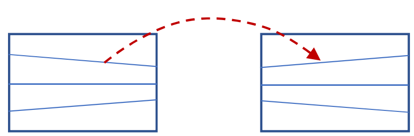
→ e.g. to compute the marginals $P_i(x_i) = \sum_{\{x_j : j \neq i\}} P(\mathbf{x})$ or $P(x_i, x_j) = \sum_{\{x_k : k \neq i, k \neq j\}} P(\mathbf{x})$

Binocular Stereo



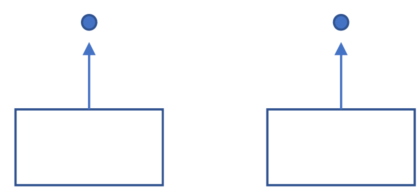


Otherwise



Epipolar Line Constraint

The geometry means that a point in the left eye can only match to points on one line in the right eye



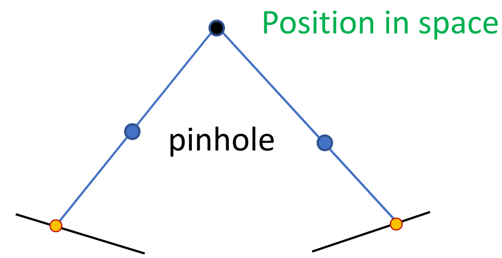
Special cue: cameras(eyes) are parallel

Binocular Stereo

So, stereo matching is a 1-D problem if the epipolar geometry is known (calibrated cameras)

Disparity : Point i in left image matches point $i+d_i$ in right image $\{d_i\}$ - disparity

Task: estimate disparity $\{d_i\}$ determines depth if matching is known,
depth is estimated by trigonometry



Energy Function / Probability Formulation

$$E[\{d_i\}] = \underbrace{\sum_i \Phi(d_i, I_L, I_R)}_{\text{data cues}} + \underbrace{\sum_i \psi(d_i, d_{i+1})}_{\text{weak smoothness constraint}}$$

data cues — e.g. $\left|F(I_L)_i - F(I_R)_{i+d_i}\right|$

weak smoothness constraint — e.g. $K(d_i - d_{i+1})$

$F(I_L)_i$: image feature, computed on left image at position i,
(e.g. derivative filters, smoothing filters)

$F(I_R)_{i+d_i}$: image feature, computed on right image at position $i+d_i$

Note: for some images the data cues are enough

E.G. $I_L =$ [+ • ★] $I_R =$ [+ • ★]

Then match (+ to +), (• to •), (★ to ★): But this almost never happens.

Energy Function / Probability Formulation

Need weak smoothness of disparity to resolve matching ambiguities

Task: solve for $D = \{d_i\}$ by minimizing

$$E\left[\{d_i\}\right] = \sum_i \Phi(d_i, I_L, I_R) + \sum_i \psi(d_i, d_{i+1})$$

➡ Use Dynamic Programming: restrict the disparity d_i to take a finite set of k-values.

Energy Function / Probability Formulation

Note: This is a very simple model of stereo

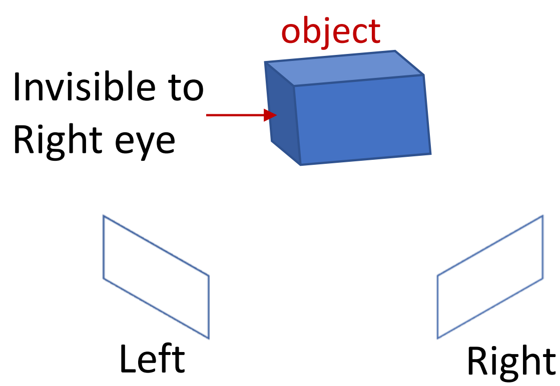
There are situations where some features are visible in one eye(camera) only

➔ These half-occluded points cannot be matched

Half-occlusion gives information.

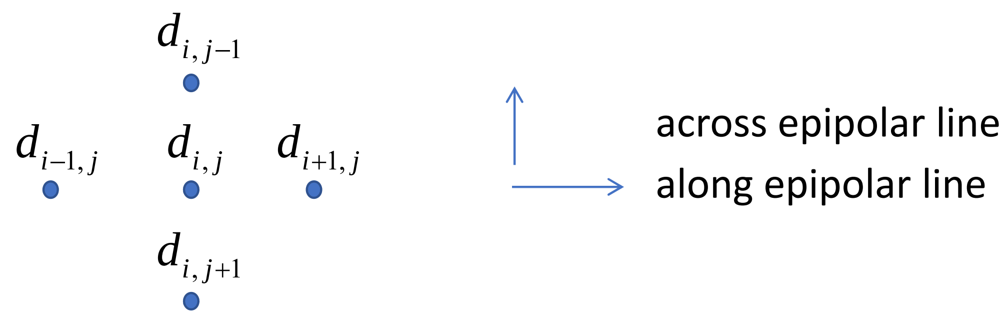
It occurs when the surface orientation changes – i.e. where smoothness of disparity is violated

Can exploit this to get better stereo.
(e.g. Geiger, Ladendorf, Yuille 1995, Belhaven & Mulford 1996)



Better stereo algorithms enforce weak smoothness across the epipolar lines – not just along -

2D Problem



$$E\left[\{d_{i,j}\}\right] = \sum_{i,j} \Phi(d_{i,j}, I_L, I_R) + \underbrace{A \sum_{i,j} \psi(d_{i,j}, d_{i+1,j})}_{\text{along eipolar line}} + \underbrace{B \sum_{i,j} \psi(d_{i,j}, d_{i,j+1})}_{\text{across eipolar line}}$$

along eipolar line · across eipolar line → weak smoothness

Use Belief Propagation → or Max-Flow to estimate $\{\hat{d}_{i,j}\} = \arg\min E\left[\{d_{i,j}\}\right]$