Plane Sweep Stereo

$$\begin{bmatrix} x_c \\ y_c \\ 1 \end{bmatrix} \approx \begin{bmatrix} x' \\ y' \\ w' \end{bmatrix} \leftarrow \begin{bmatrix} K & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} R & t \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix}$$

(cam ↓, world ↓)

Setting:

Cameras are not rectified

Cameras are calibrated ($K_l, [R|t]_l, [R|t]_r$; K_r are known)

Standard Stereo:

for each pixel:
  for each disparity:
    compute match cost

Plane Sweep Stereo:

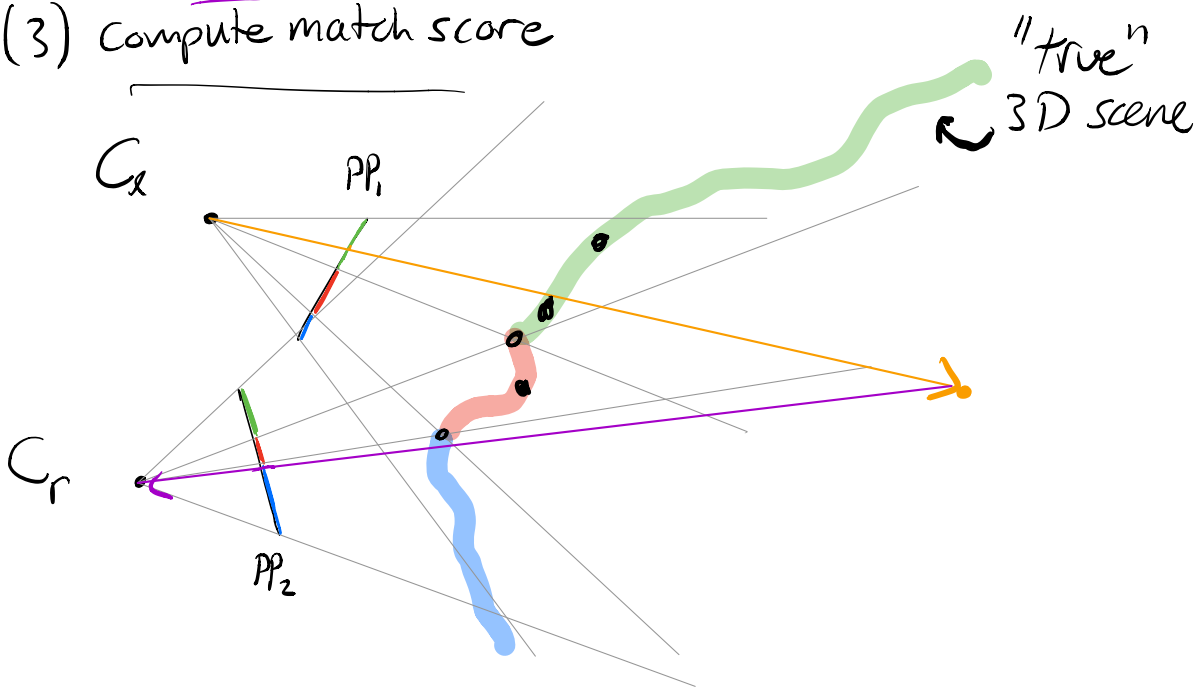
for each disparity:
  for each pixel:
    Compute match cost

Intuition:

(1) "unproject" a pixel to a hypothesized depth d

(2) "reproject" that 3D point back into the other camera

(3) Compute match score



Details:

(1) "Unproject":

- convert pixels to camera coords (K_l^{-1})
- move to depth d (d)
- put in world coords $[R;t]_l^{-1}$

world → $\begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix}$ ≈ $[R;t]_l^{-1}$ (cam at depth d) d K_l^{-1} (cam on img plane) $\begin{bmatrix} x_l \\ y_l \\ 1 \end{bmatrix}$

(2) "Reproject"

- world to cam $[R;t]_r$
- cam to pixel K_r

$$\begin{bmatrix} x_r \\ y_r \\ 1 \end{bmatrix} \approx K_r [R;t]_r \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix}$$

(3) compute match score

Insight: "unproject-reproject" is a homography!

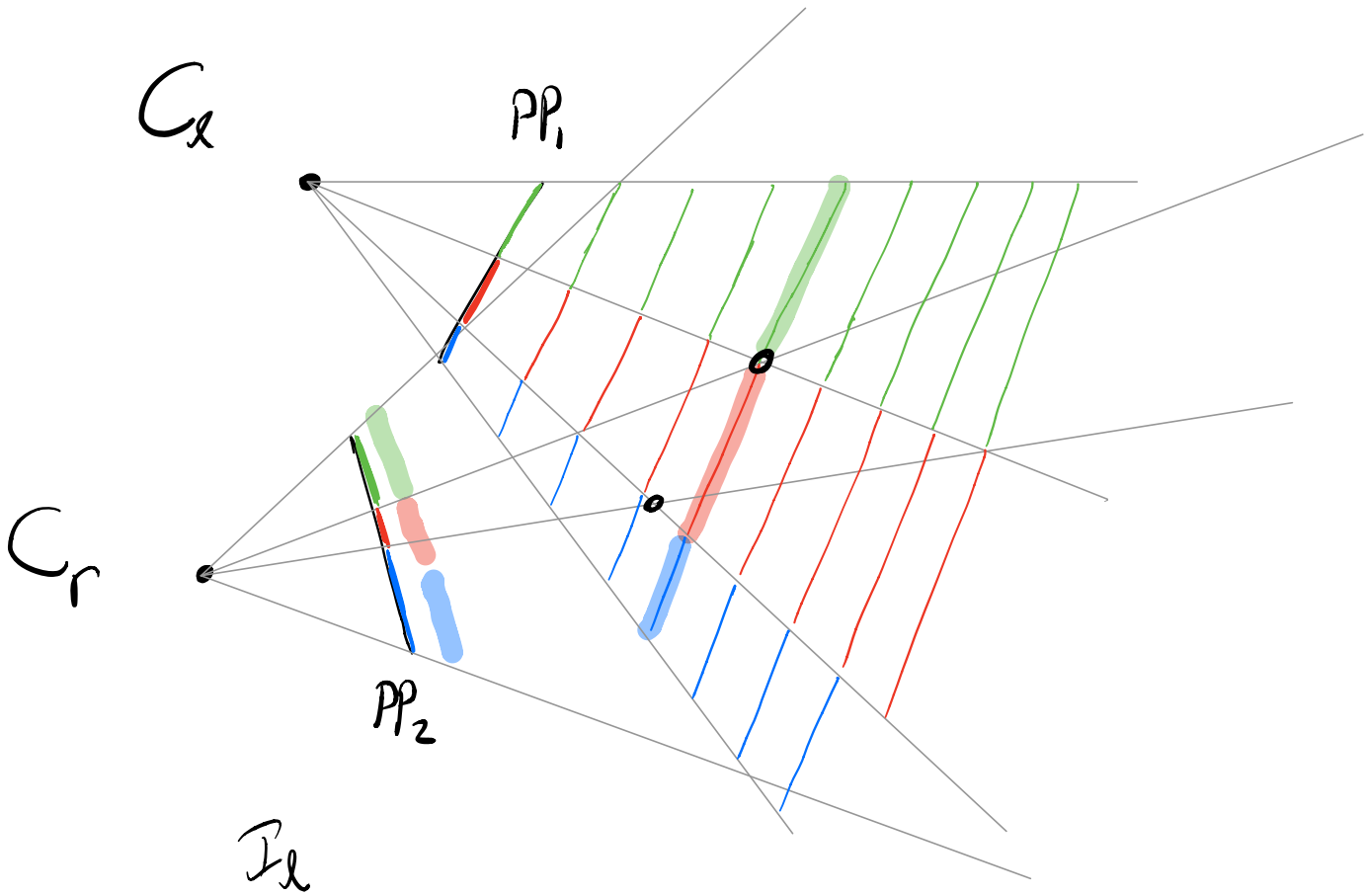
Strategy: (1) unproject 4 corners of I_l

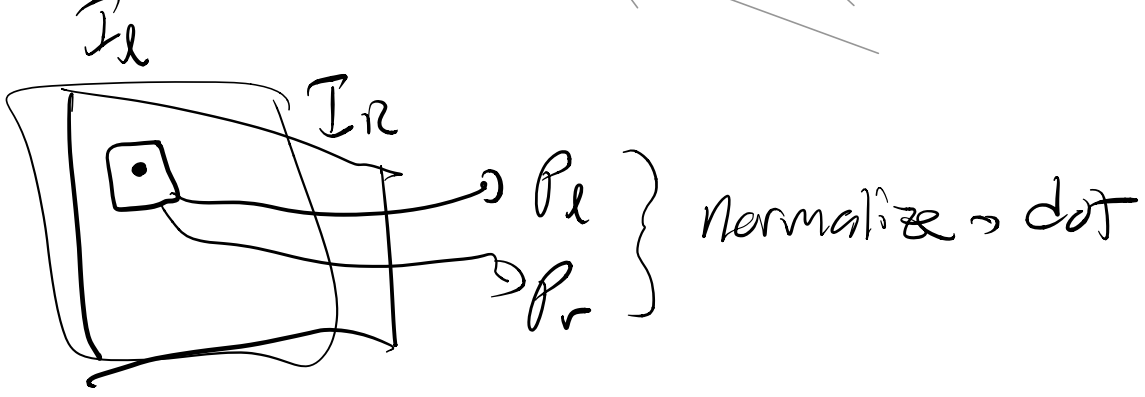
(2) reproject

(3) fit H from 4 correspondences

(4) Warp I_l to I_r

(5) Compute NCC on whole img at once!





$$[R;t] = \begin{pmatrix} R & 0 \\ 0\,0\,0 & 1 \end{pmatrix} \begin{bmatrix} I_{3\times3} & t \\ 0\,0\,0 & 1 \end{bmatrix} = \begin{pmatrix} R & R\cdot t \\ 0\,0\,0 & 1 \end{pmatrix}$$

(translate then rotate)

$$\text{inv} \begin{pmatrix} R & R\cdot t \\ 0\,0\,0 & 1 \end{pmatrix} = \begin{bmatrix} R^T & -t \\ 0\,0\,0 & 1 \end{bmatrix}$$