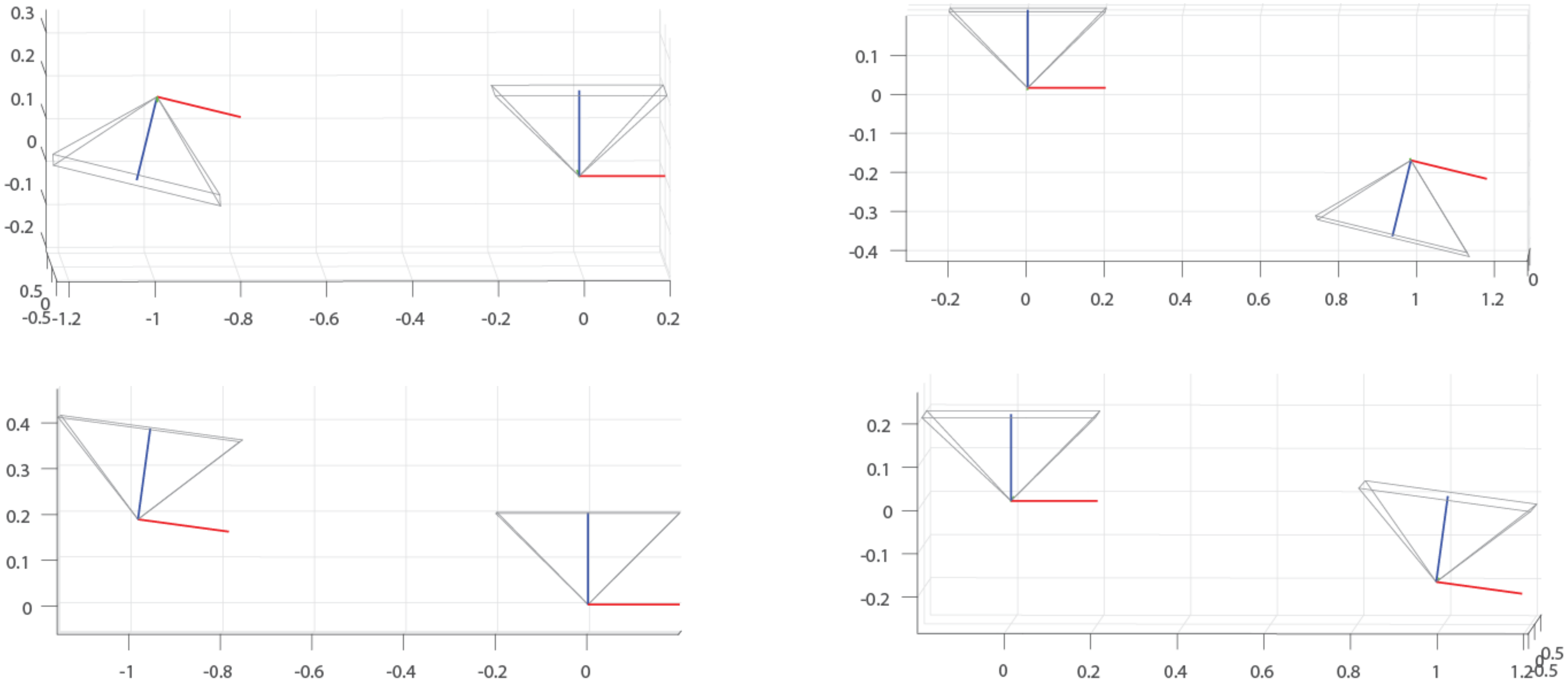
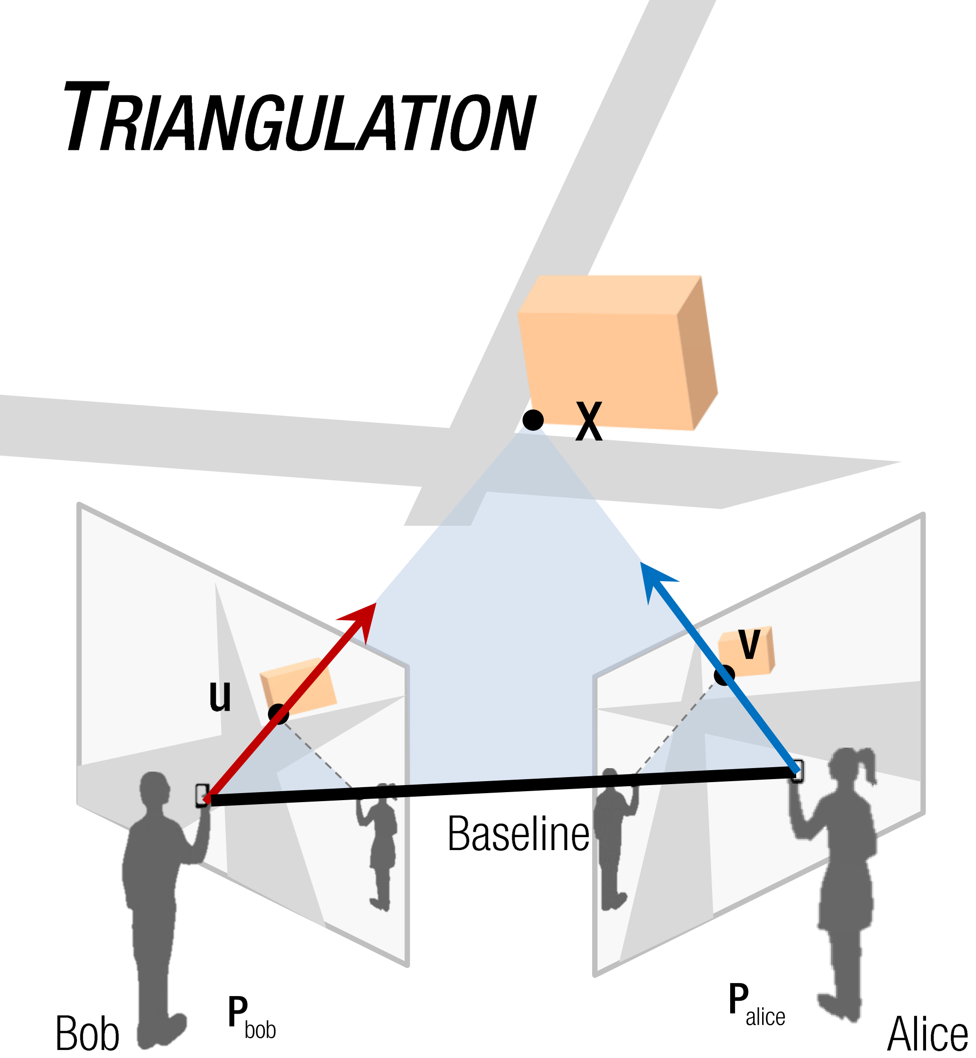
TRIANGULATION

HYUN SOO PARK

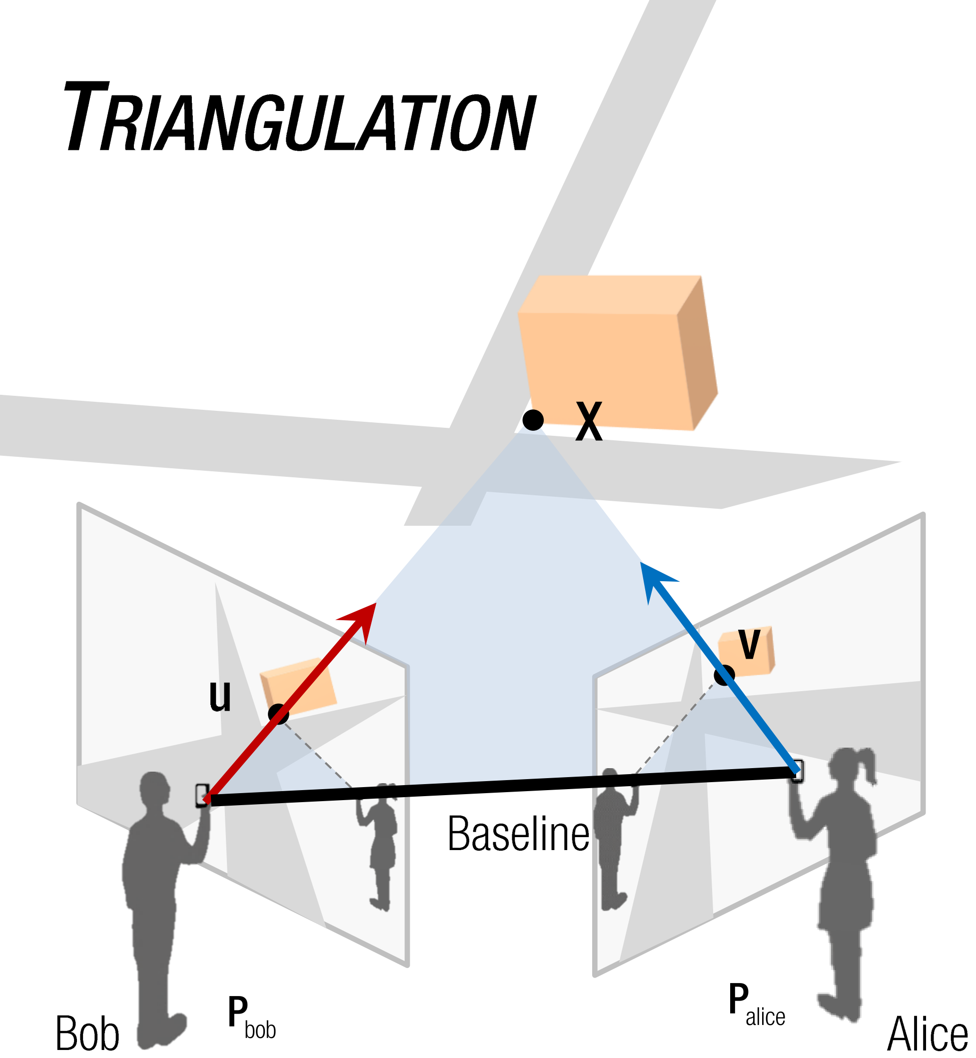
Pose Disambiguation



TRIANGULATION



TRIANGULATION

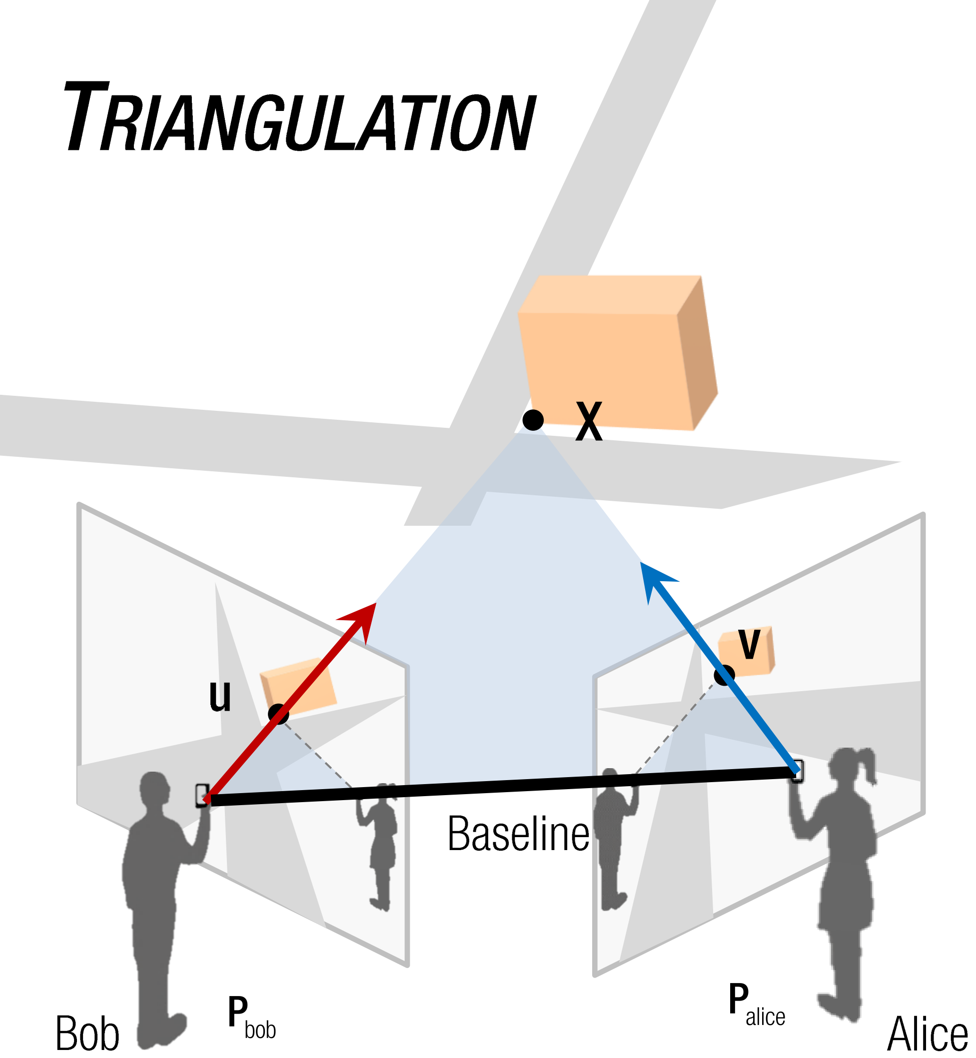


General camera pose

$$\lambda_1 \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} = \mathbf{P}_{bob} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix}$$

Two 3D vectors are parallel.

TRIANGULATION



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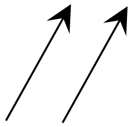
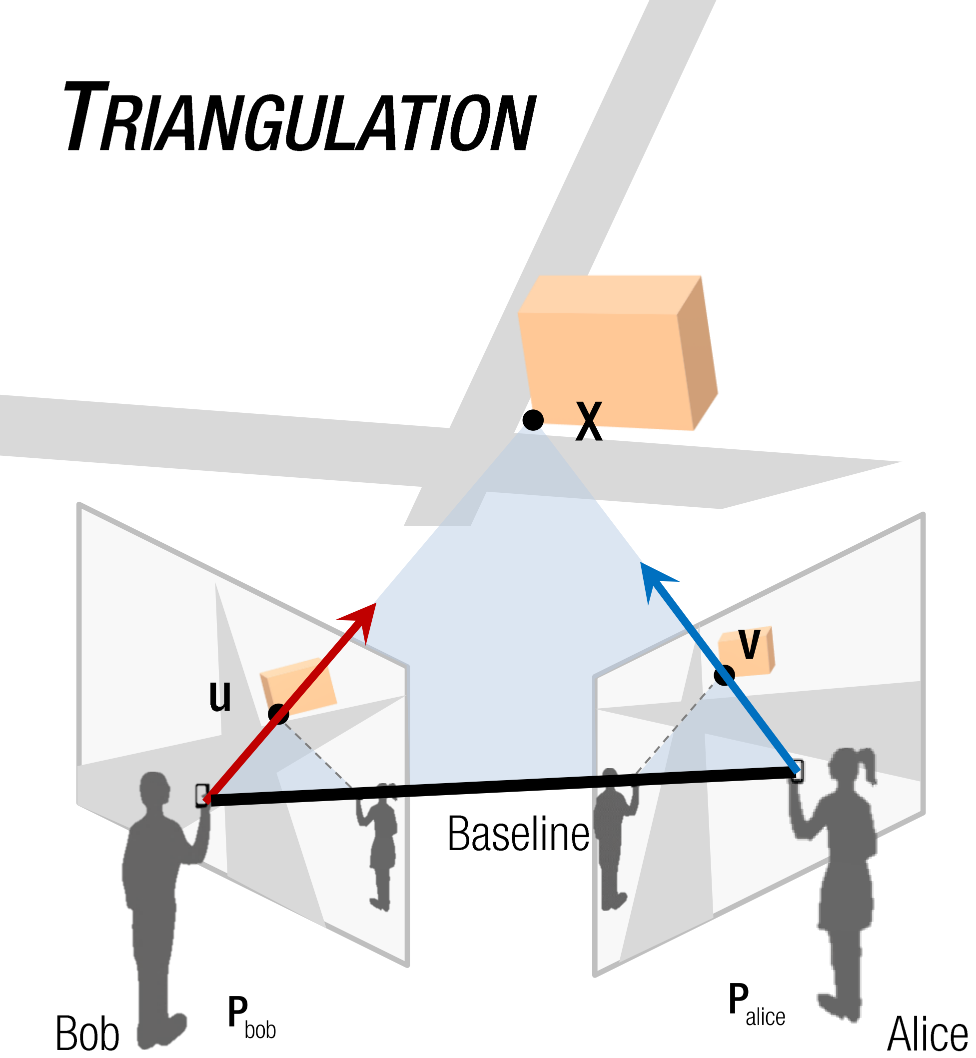
$$\lambda_1 \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} = \mathbf{P}_{bob} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix}$$



Two 3D vectors are parallel.

$$\rightarrow \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} \times \mathbf{P}_{bob} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix} = \mathbf{0}$$

TRIANGULATION



General camera pose

$$\lambda_1 \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} = \mathbf{P}_{\text{bob}} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix}$$

Two 3D vectors are parallel.

$$\rightarrow \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} \times \mathbf{P}_{\text{bob}} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix} = \mathbf{0}$$

$$\rightarrow \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix}_{\times} \mathbf{P}_{\text{bob}} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix} = \mathbf{0}$$

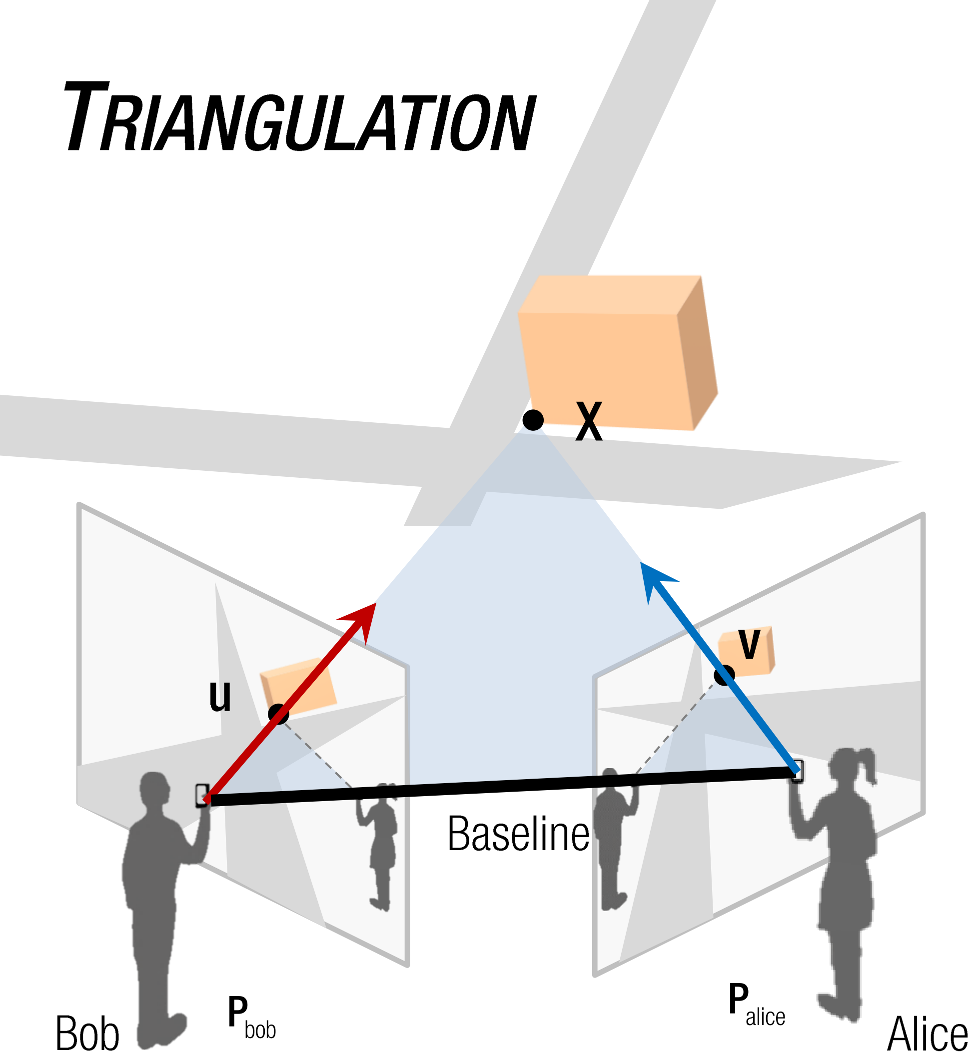
: Knowns

: Unknowns

Skew-symmetric matrix

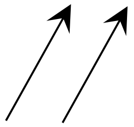
$$\begin{bmatrix} a \\ b \\ c \end{bmatrix}_{\times} = \begin{bmatrix} 0 & -c & b \\ c & 0 & -a \\ -b & a & 0 \end{bmatrix}$$

TRIANGULATION



General camera pose

$$\lambda_1 \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} = \mathbf{P}_{bob} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix}$$



Two 3D vectors are parallel.

$$\rightarrow \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} \times \mathbf{P}_{bob} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix} = \mathbf{0}$$

$$\rightarrow \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix}_{\times} \mathbf{P}_{bob} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix} = \mathbf{0}$$

: Knowns

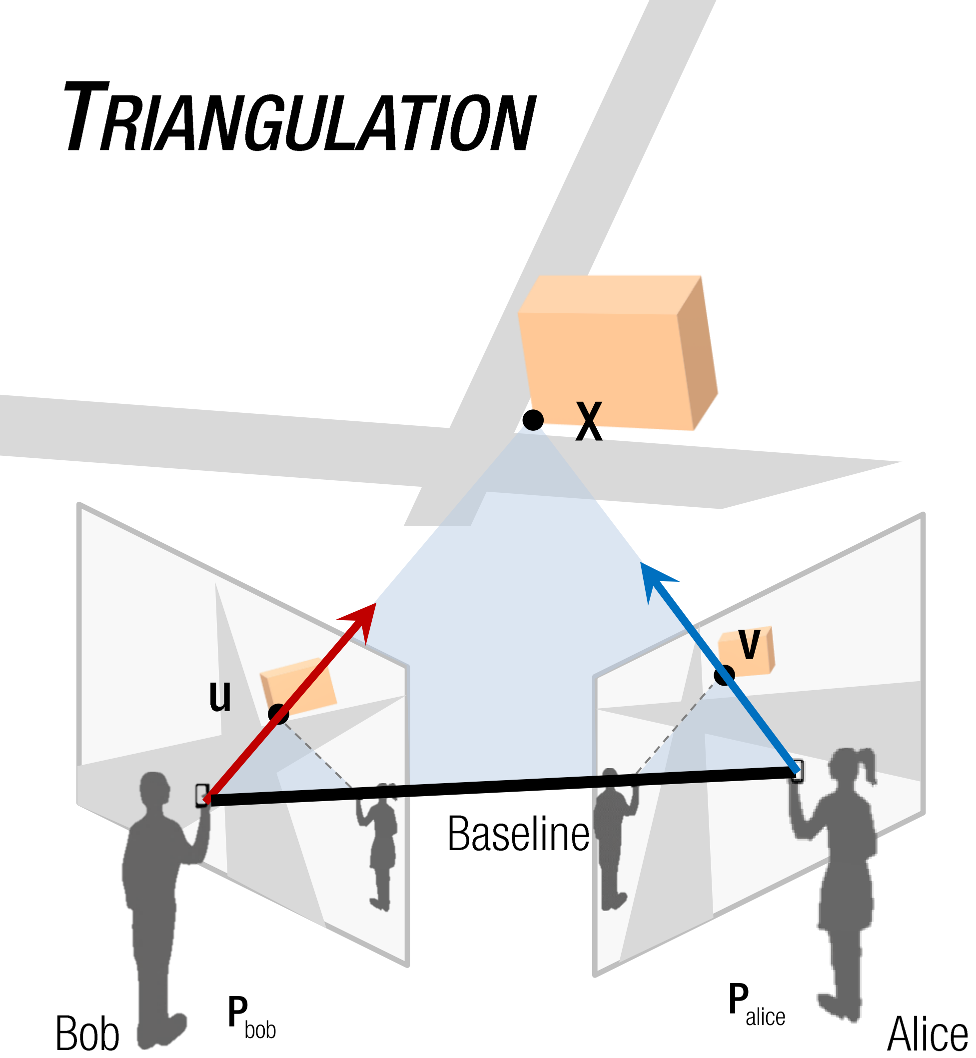
: Unknowns

3x4

Can we solve for **X**? (single view reconstruction)

Why not?

TRIANGULATION



General camera pose

$$\lambda_1 \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} = \mathbf{P}_{bob} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix}$$

Two 3D vectors are parallel.

$$\rightarrow \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} \times \mathbf{P}_{bob} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix} = \mathbf{0}$$

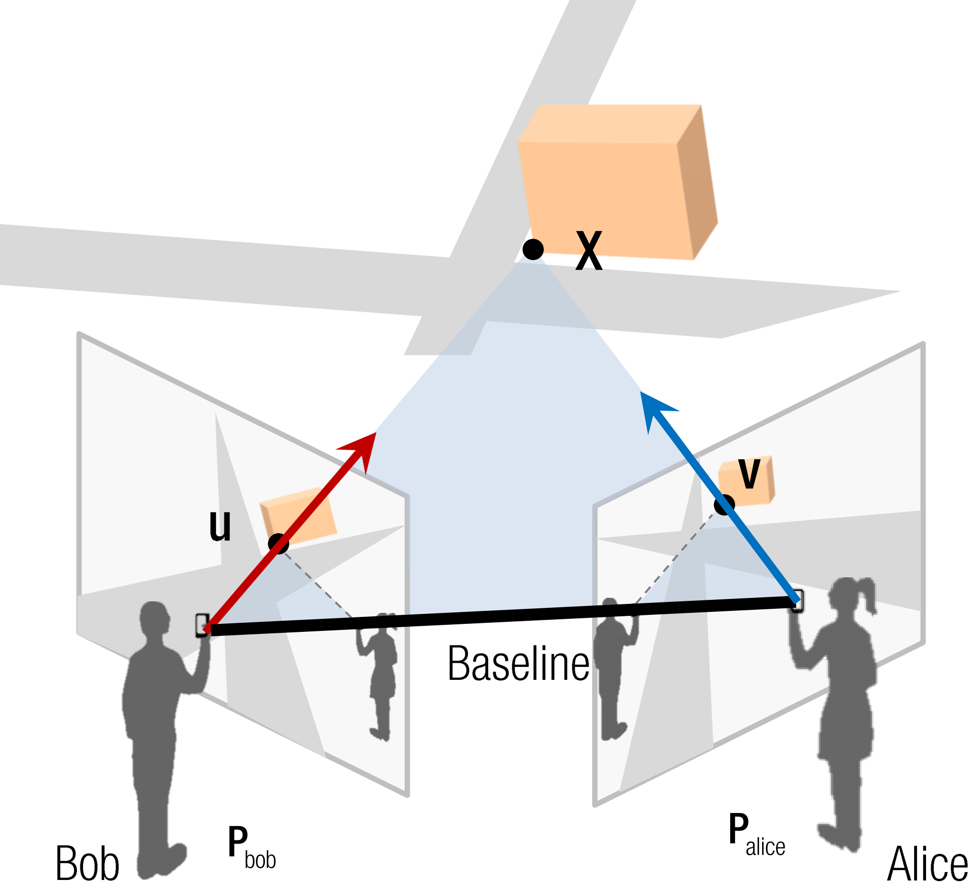
$$\rightarrow \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix}_{\times} \mathbf{P}_{bob} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix} = \mathbf{0}$$

2x4

: Knowns

: Unknowns

TRIANGULATION



General camera pose

$$\lambda_1 \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} = \mathbf{P}_{\text{bob}} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix}$$

Two 3D vectors are parallel.

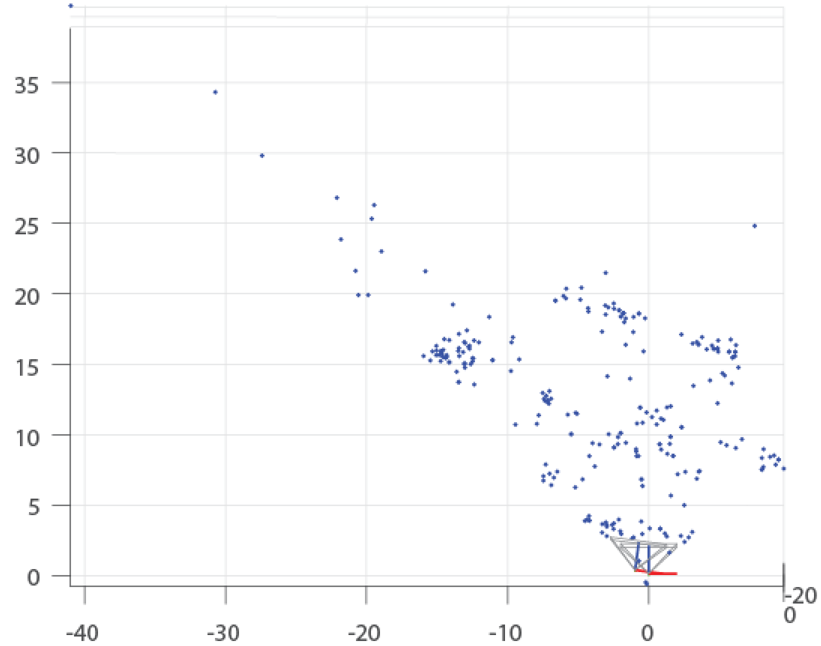
$$\rightarrow \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix} \times \mathbf{P}_{\text{bob}} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix} = \mathbf{0}$$

$$\rightarrow \begin{bmatrix} \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix}_\times \mathbf{P}_{\text{bob}} \\ \begin{bmatrix} \mathbf{v} \\ 1 \end{bmatrix}_\times \mathbf{P}_{\text{alice}} \end{bmatrix} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix} = \mathbf{0}$$

4x4

: Knowns

: Unknowns



$$\begin{bmatrix} \begin{bmatrix} \mathbf{u} \\ 1 \end{bmatrix}_{\times} \mathbf{P}_{\text{bob}} \\ \begin{bmatrix} \mathbf{v} \\ 1 \end{bmatrix}_{\times} \mathbf{P}_{\text{alice}} \end{bmatrix} \begin{bmatrix} \mathbf{X} \\ 1 \end{bmatrix} = \mathbf{0}$$

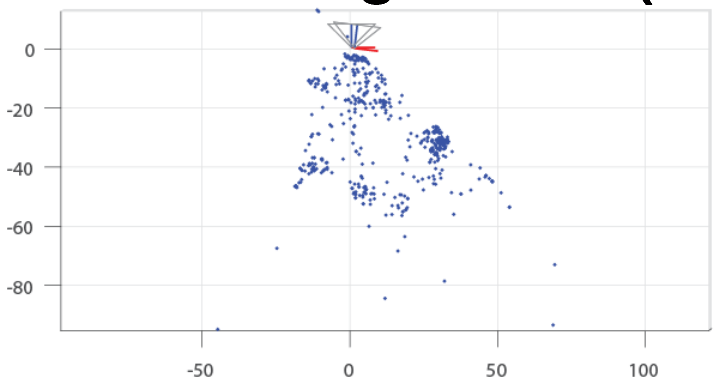
Camera Pose Disambiguation (Cheirality)

Cheirality condition:

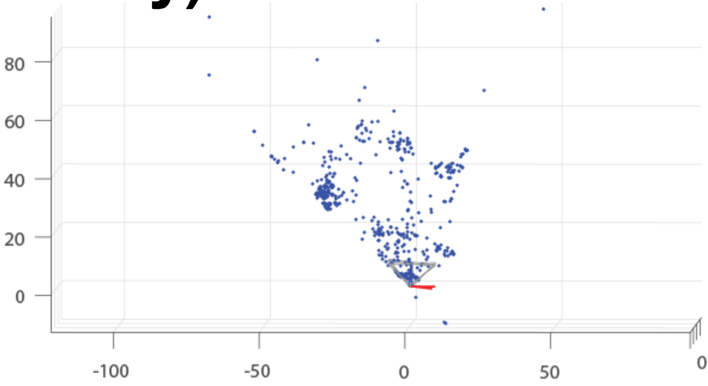
$$\mathbf{r}_3^T (\mathbf{X} - \mathbf{C}) > 0$$

where

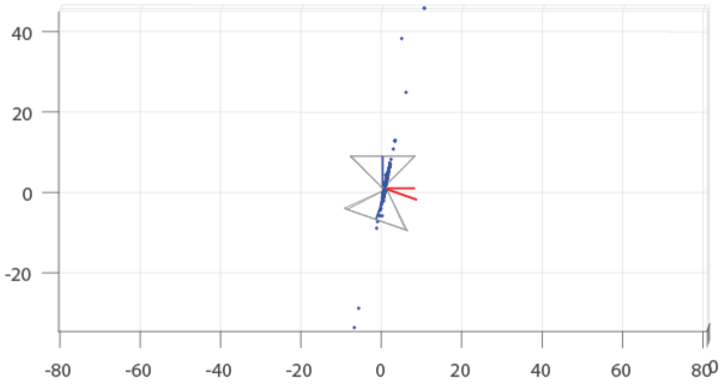
$$\mathbf{R} = \begin{bmatrix} \mathbf{r}_1^T \\ \mathbf{r}_2^T \\ \mathbf{r}_3^T \end{bmatrix}$$



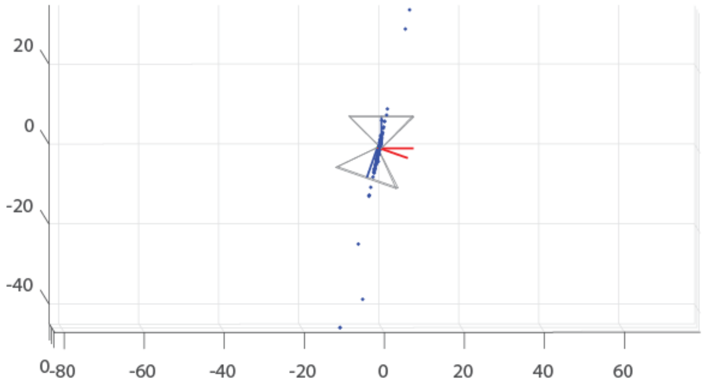
(a) nValid = 10



(b) nValid = 488



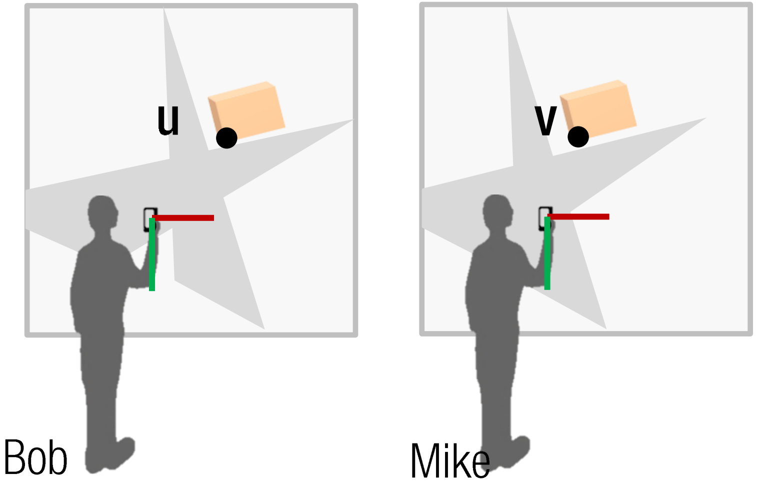
(c) nValid = 0



(d) nValid = 0

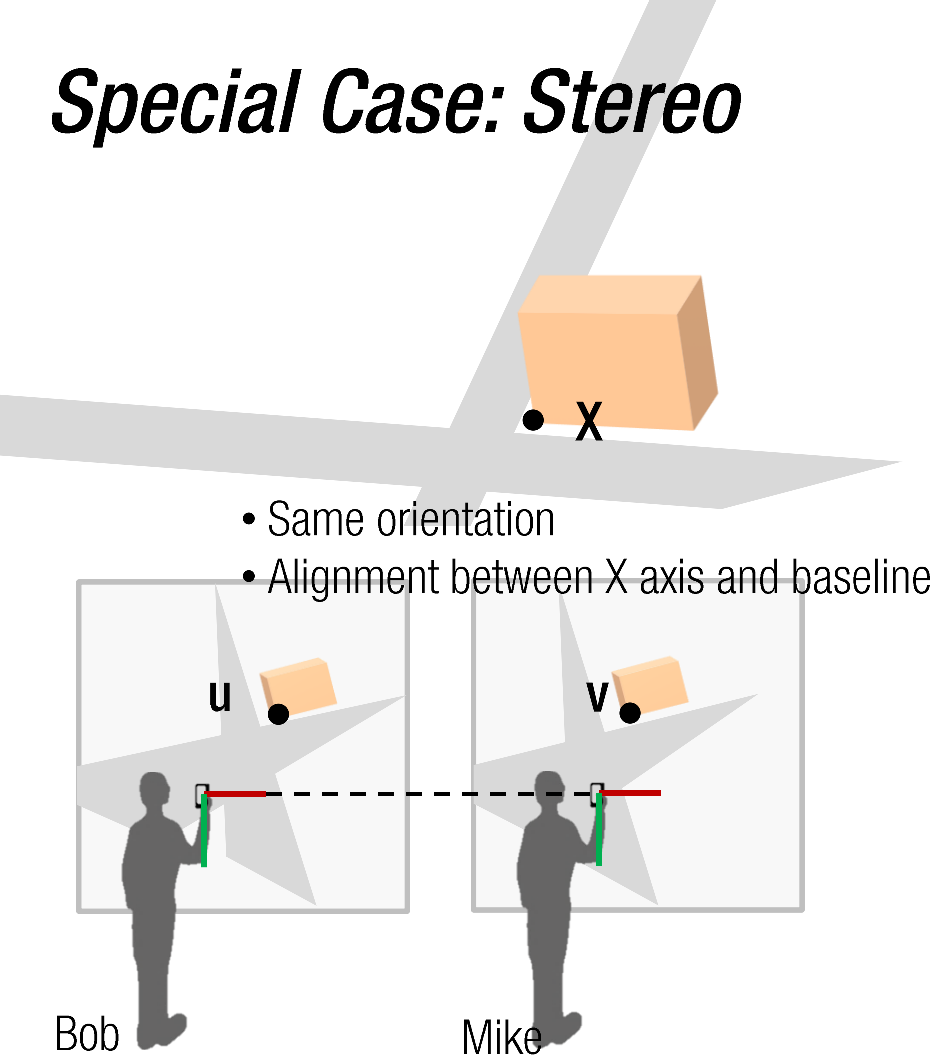
Special Case: Stereo

- Same orientation

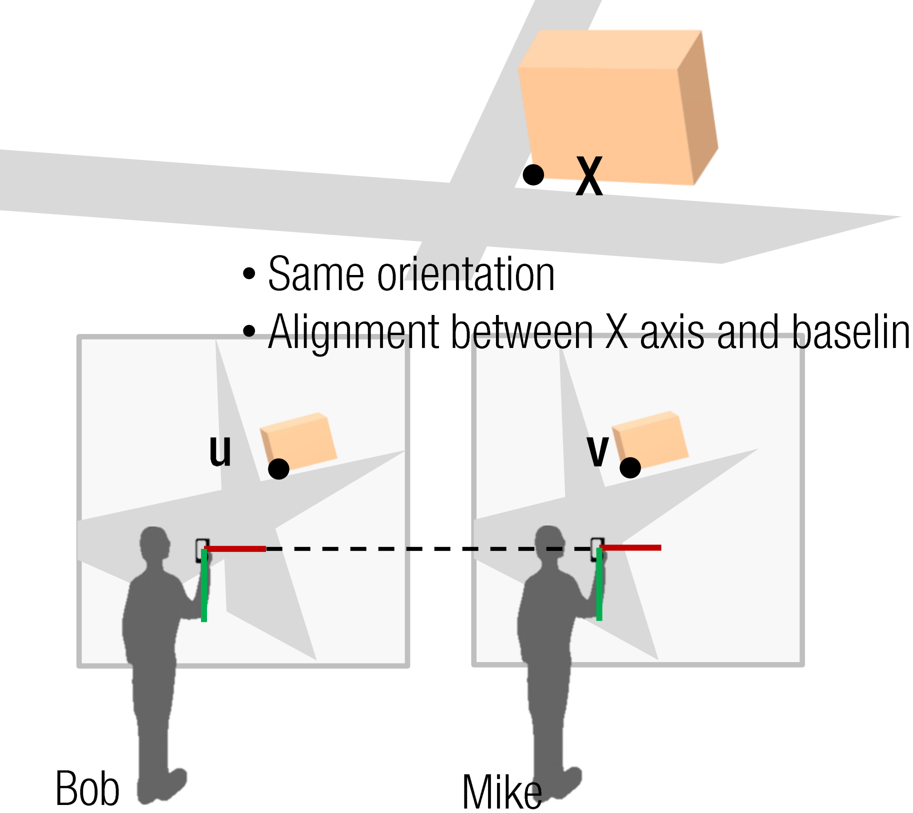


Special Case: Stereo

- Same orientation
- Alignment between X axis and baseline

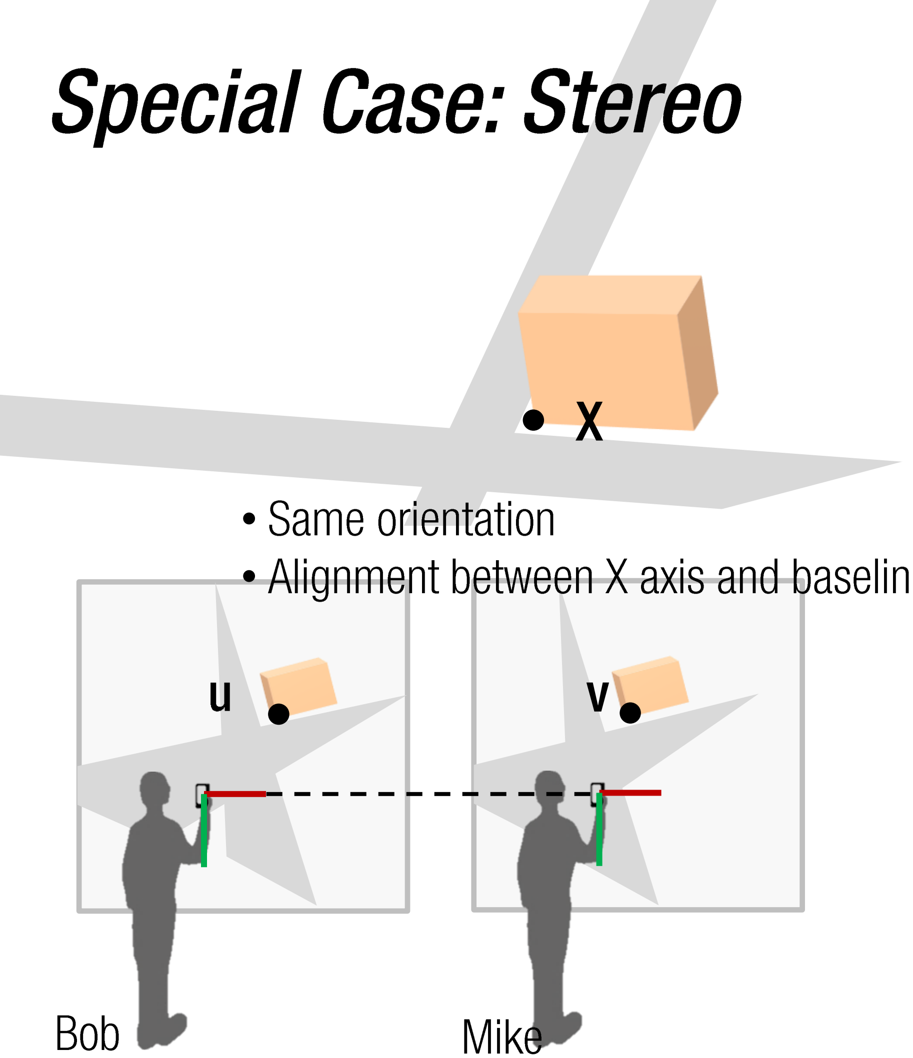


Special Case: Stereo



- Same orientation
- Alignment between X axis and baseline

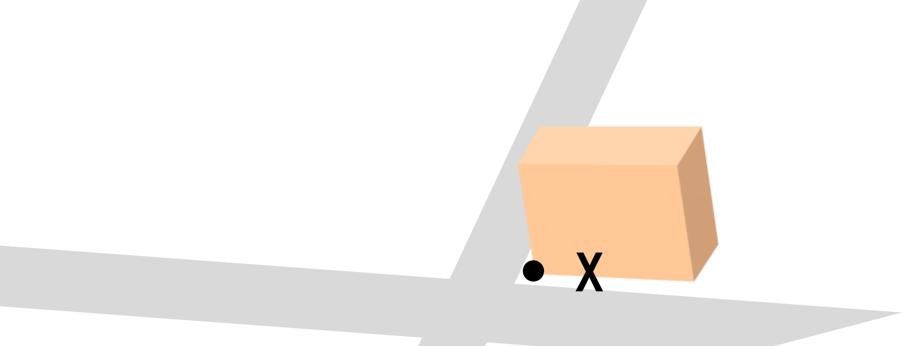
Special Case: Stereo



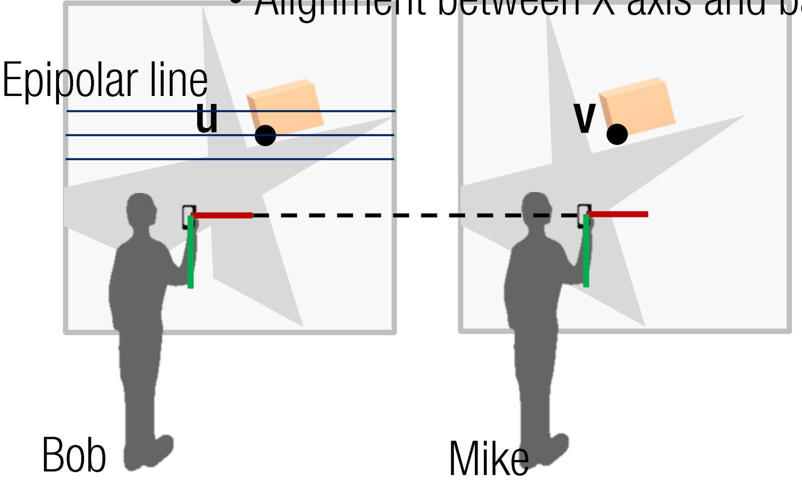
- Same orientation
- Alignment between X axis and baseline

Top view

Special Case: Stereo



- Same orientation
- Alignment between X axis and baseline

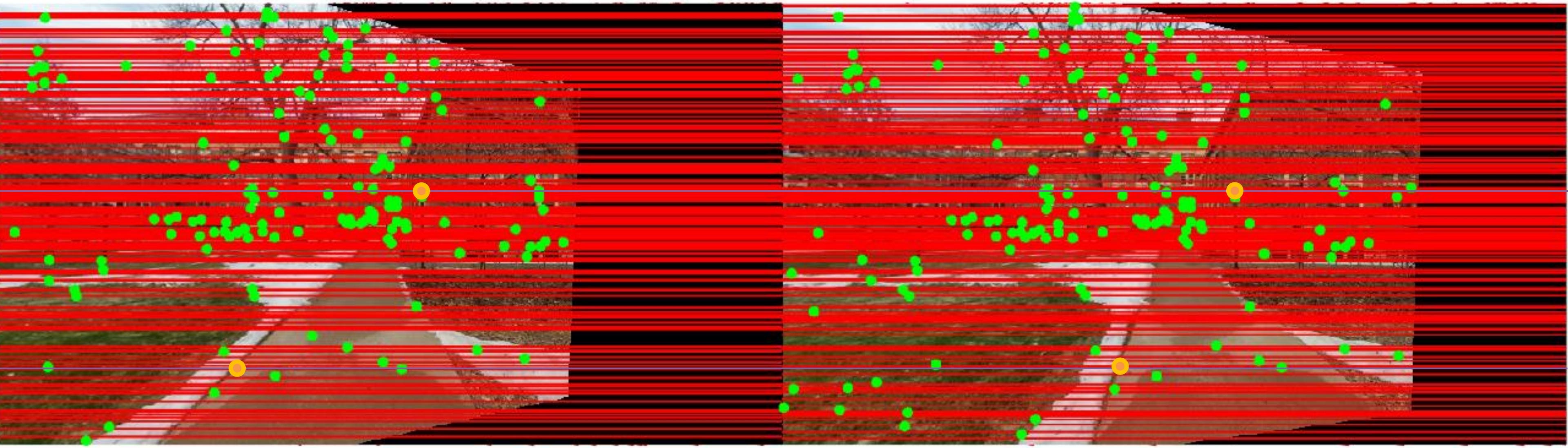


Epipole?
Point at infinity

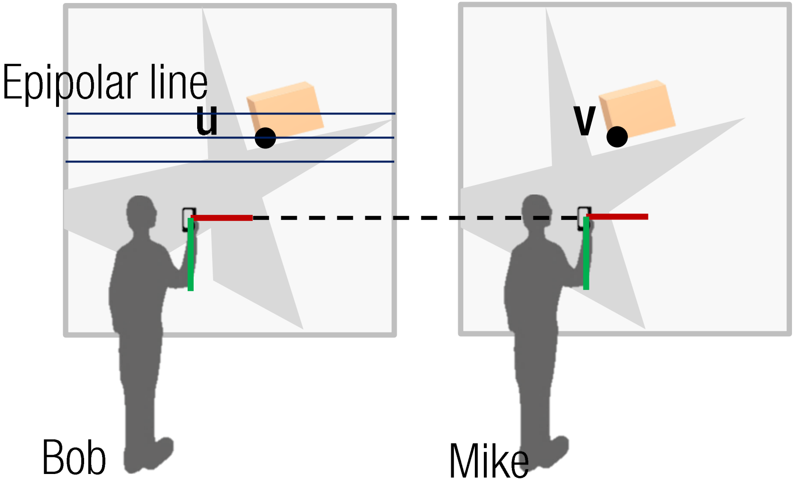
Special Case: Stereo

Special Case: Stereo

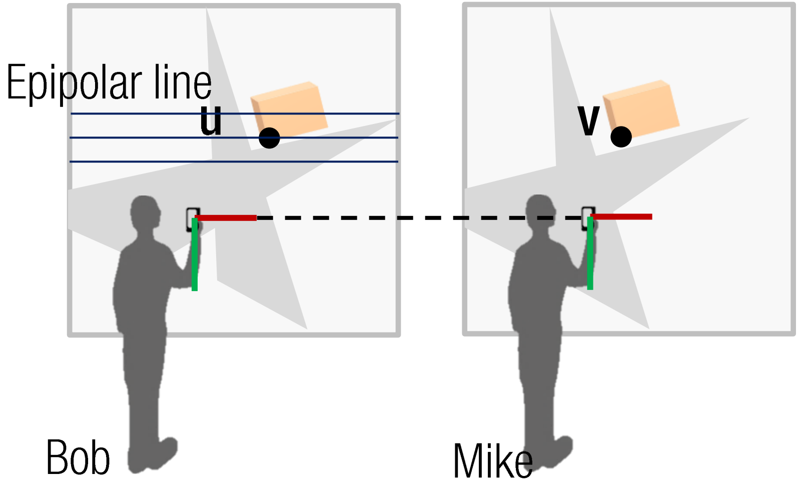
Special Case: Stereo

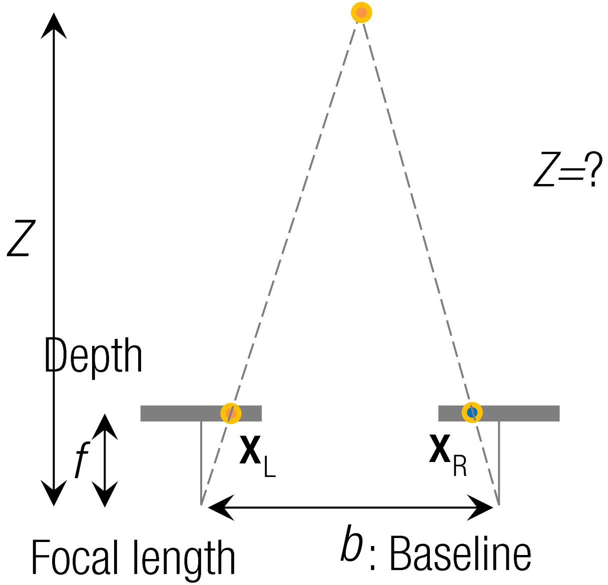


Special Case: Stereo



Special Case: Stereo





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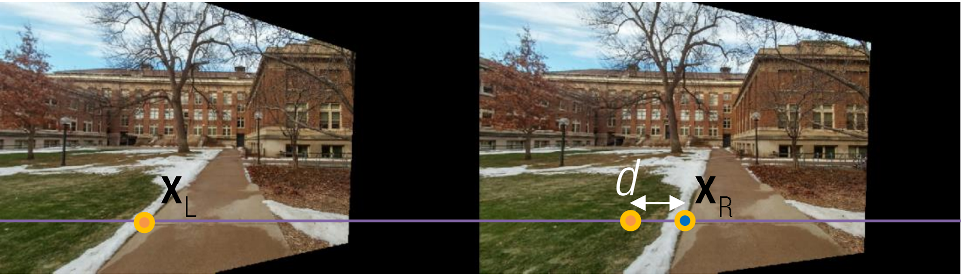

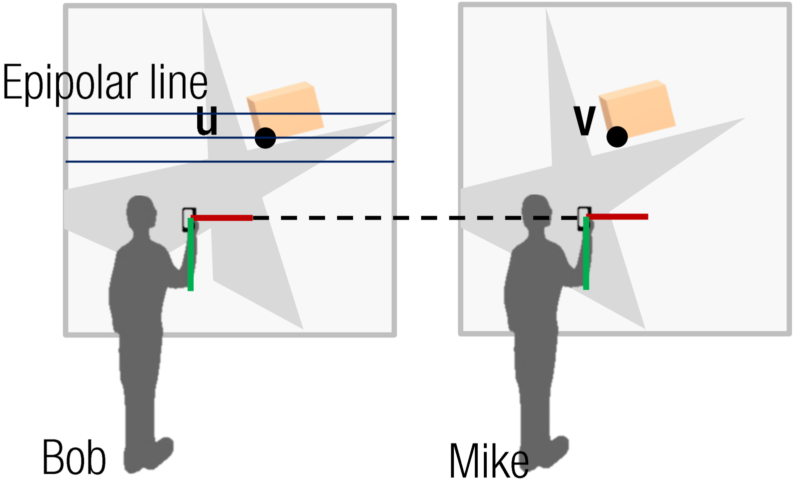

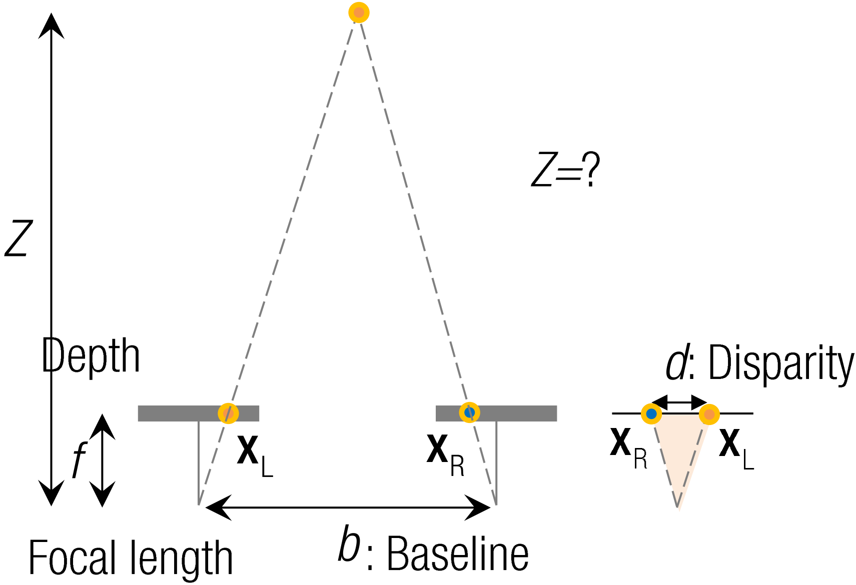

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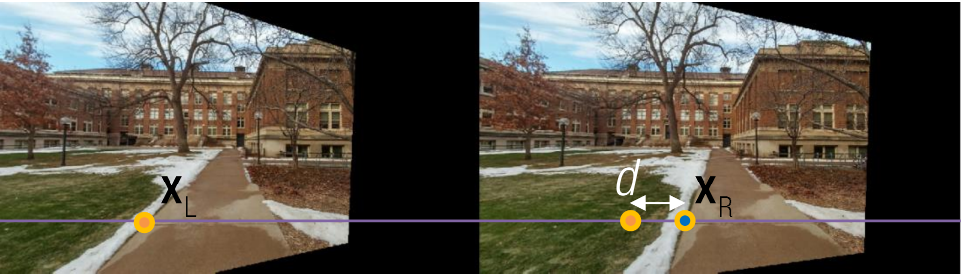

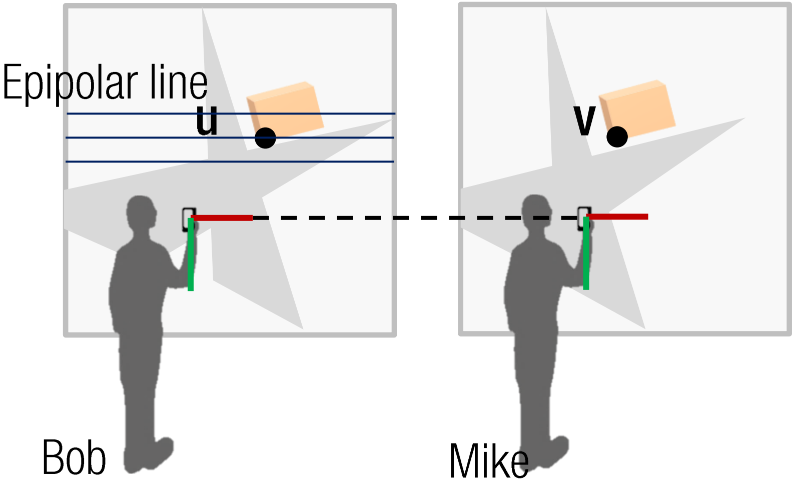

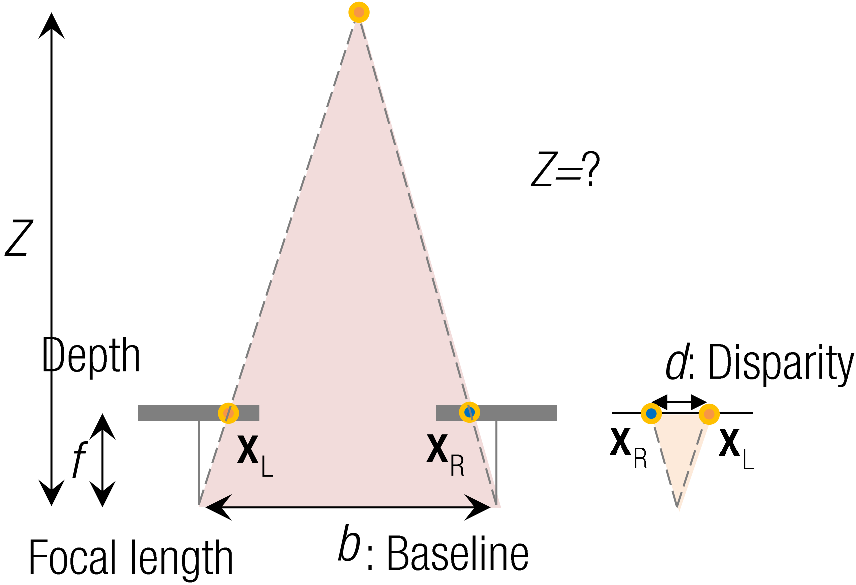

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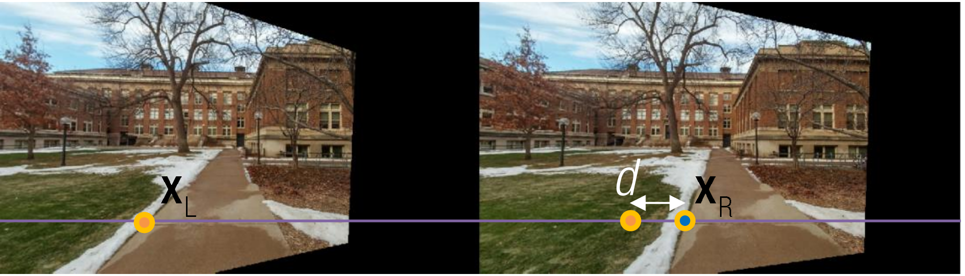
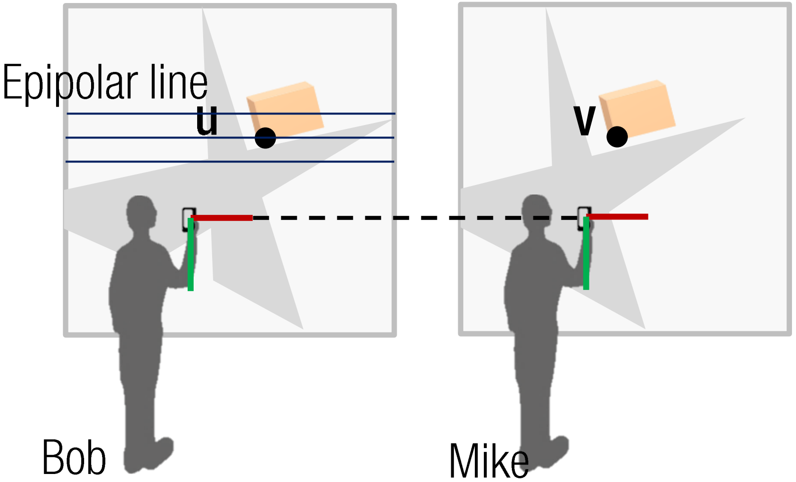
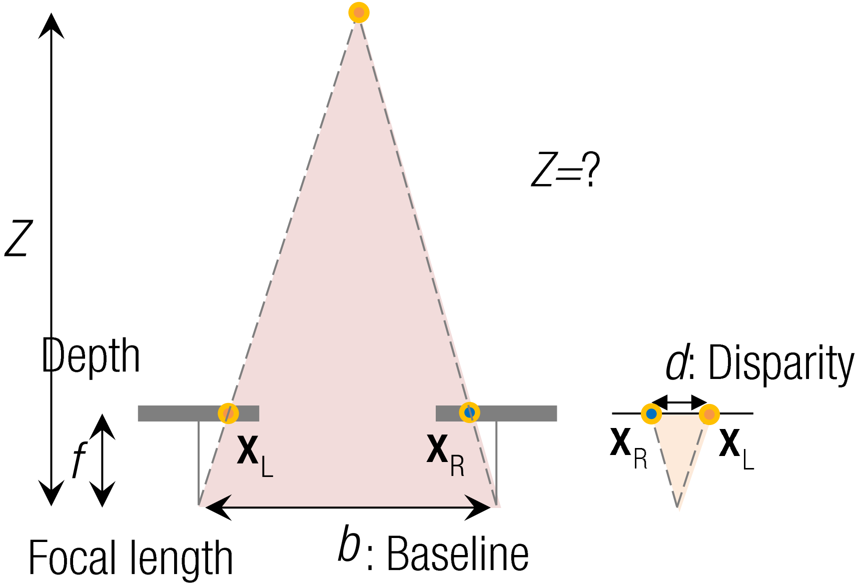
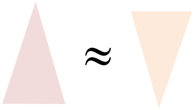






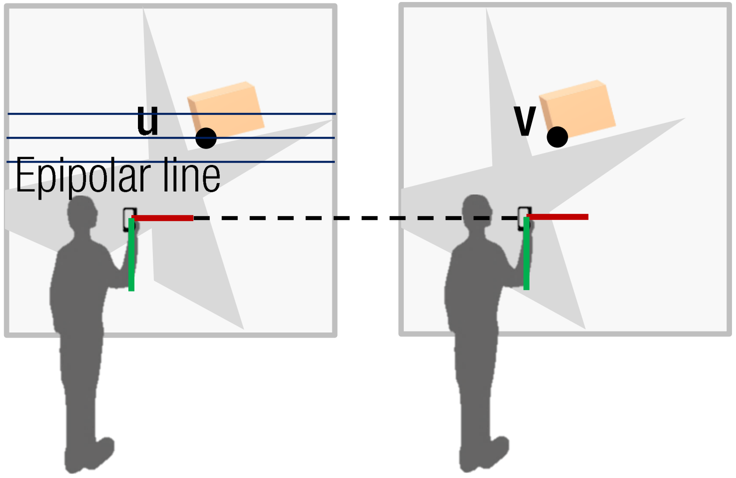


$$\frac{Z}{b} = \frac{f}{d} \rightarrow Z = b\frac{f}{d}$$

Two triangles are similar.

Special Case: Stereo

Special Case: Stereo



$$P_{bob} = K\begin{bmatrix} I & 0 \end{bmatrix} \qquad P_{mike} = KR\begin{bmatrix} I & -C \end{bmatrix}$$

- Same orientation

$$\mathbf{R}_{rect} = \begin{bmatrix} \mathbf{r}_x^T \\ \mathbf{r}_y^T \\ \mathbf{r}_z^T \end{bmatrix}$$

- Alignment between X axis and baseline

$$\mathbf{r}_x = \frac{\mathbf{C}}{\|\mathbf{C}\|}$$

$$\mathbf{r}_z = \frac{\tilde{\mathbf{r}}_z - (\tilde{\mathbf{r}}_z \cdot \mathbf{r}_x)\mathbf{r}_x}{\|\tilde{\mathbf{r}}_z - (\tilde{\mathbf{r}}_z \cdot \mathbf{r}_x)\mathbf{r}_x\|}$$: Orthogonal projection

where $\tilde{\mathbf{r}}_z = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$

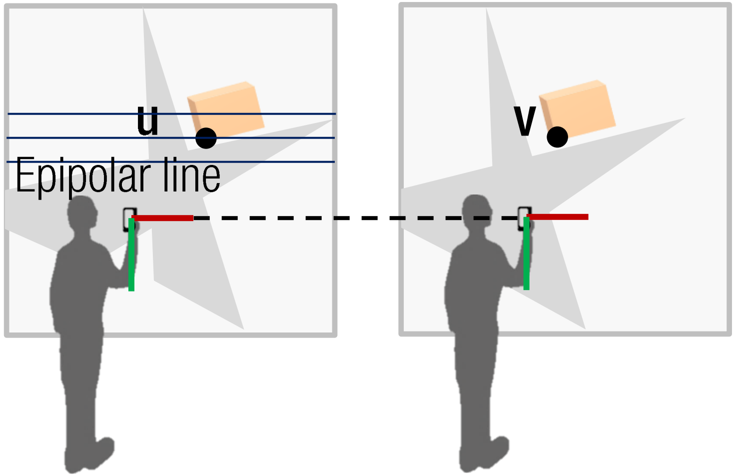
$$\mathbf{r}_y = \mathbf{r}_z \times \mathbf{r}_x$$

Special Case: Stereo

Homography by pure rotation: $\mathbf{R}_{rect}$

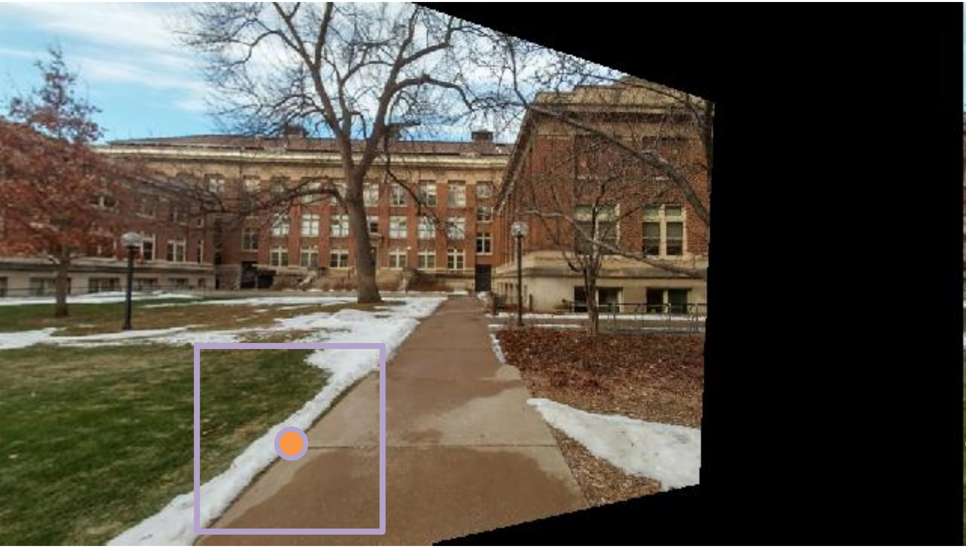
$$\mathbf{H}_{bob} = \mathbf{K}\mathbf{R}_{rect}\mathbf{K}^{-1}$$

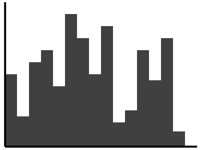
$$\mathbf{H}_{mike} = \mathbf{K}\mathbf{R}_{rect}\mathbf{R}^{T}\mathbf{K}^{-1}$$



$$\mathbf{P}_{bob} = \mathbf{K}\begin{bmatrix}\mathbf{I} & \mathbf{0}\end{bmatrix} \qquad \mathbf{P}_{mike} = \mathbf{K}\mathbf{R}\begin{bmatrix}\mathbf{I} & -\mathbf{C}\end{bmatrix}$$

Dense Feature Matching using SIFT Flow





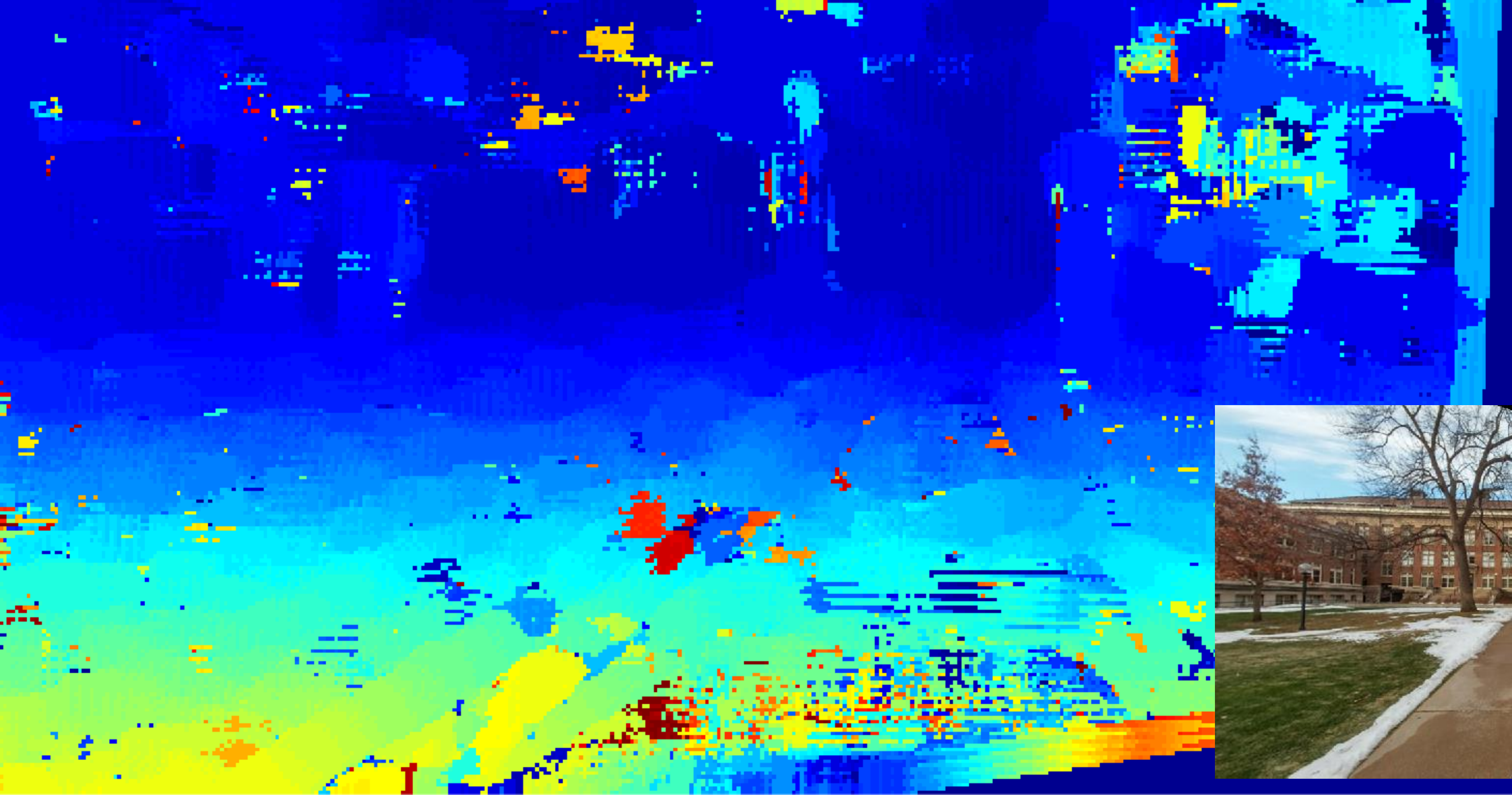
descriptor1

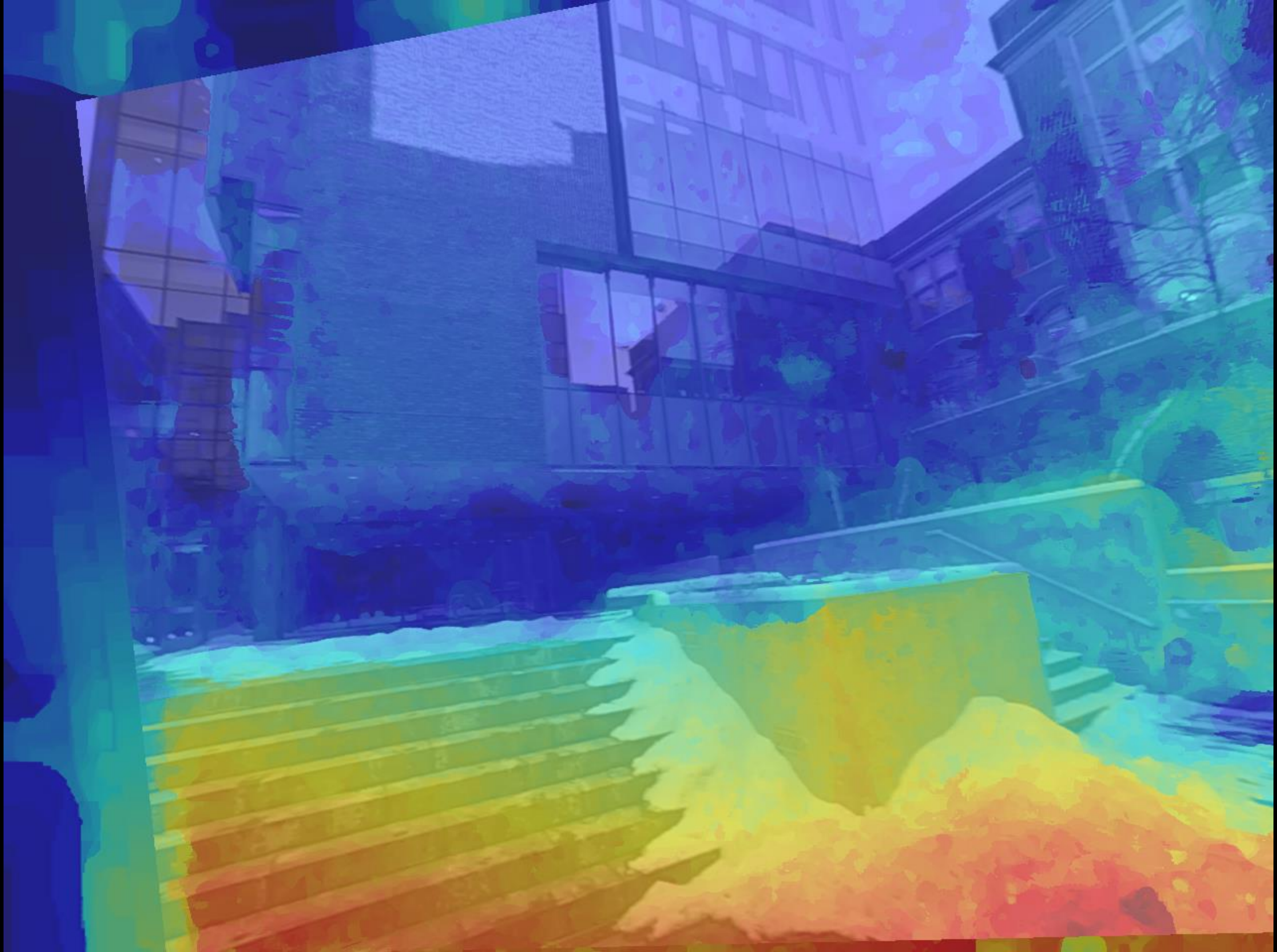
Find a minimum distance over the epipolar line

descriptor2

Disparity Map: Stereo Matching using SIFT Flow

Disparity Map = Inverse Depth






maxell
VIDEOCASSETTE


maxell
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EgoMotion Dataset (outdoor)

Dense Reconstruction using a Monocular Camera

Structure from Motion (SfM)

COLMAP

3.6

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Docs » COLMAP

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COLMAP

Sparse model of central Rome using 21K photos produced by COLMAP's SfM pipeline.

Dense models of several landmarks produced by COLMAP's MVS pipeline.

About

https://www.youtube.com/watch?v=mTBPGuPLI5Y

https://www.youtube.com/watch?v=PySBQ8Q_R8k

https://www.insidescience.org/video/motion-capture-inside-out

https://www.youtube.com/watch?v=SOpwHaQnRSY