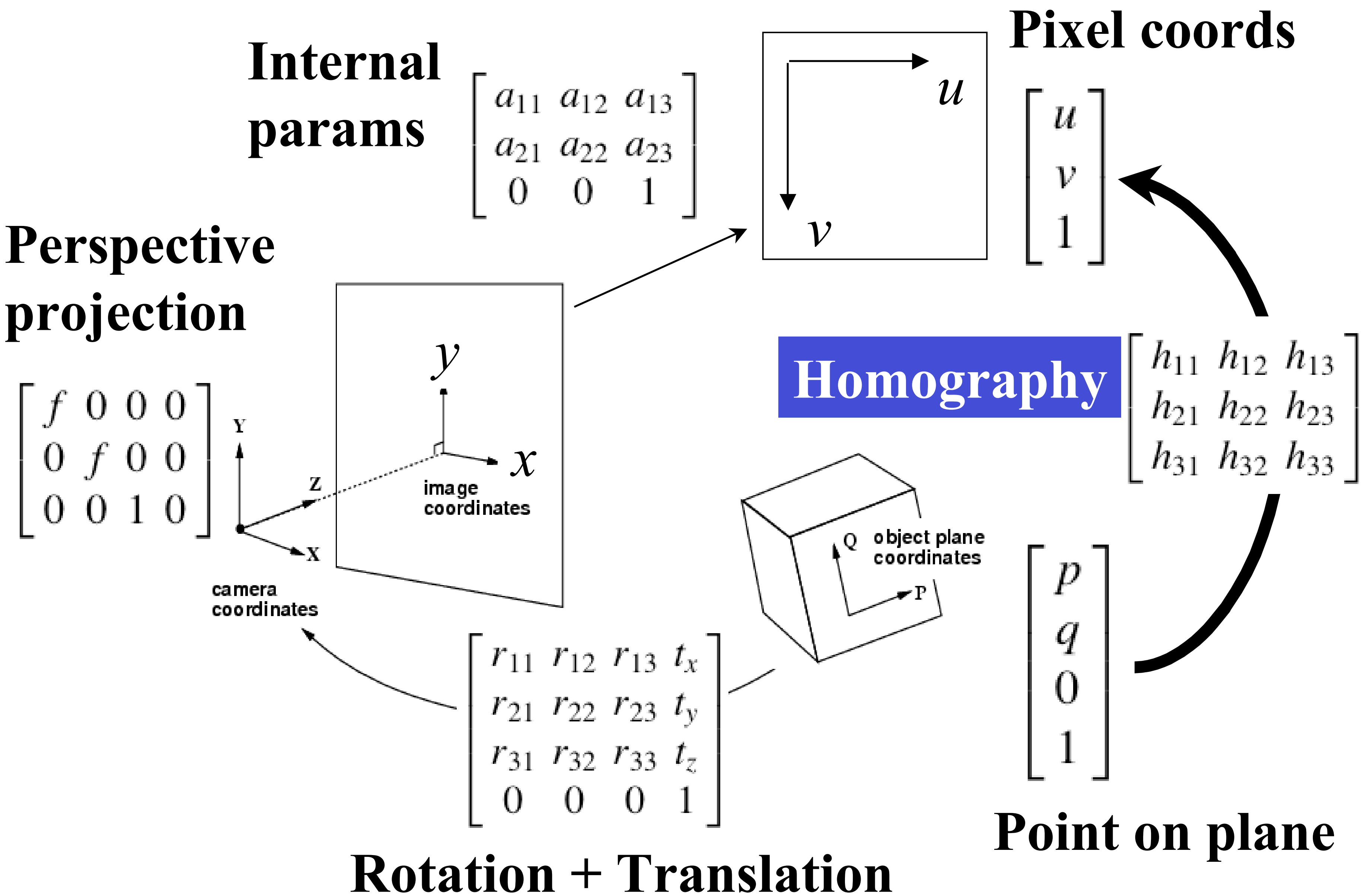
Lecture 17:

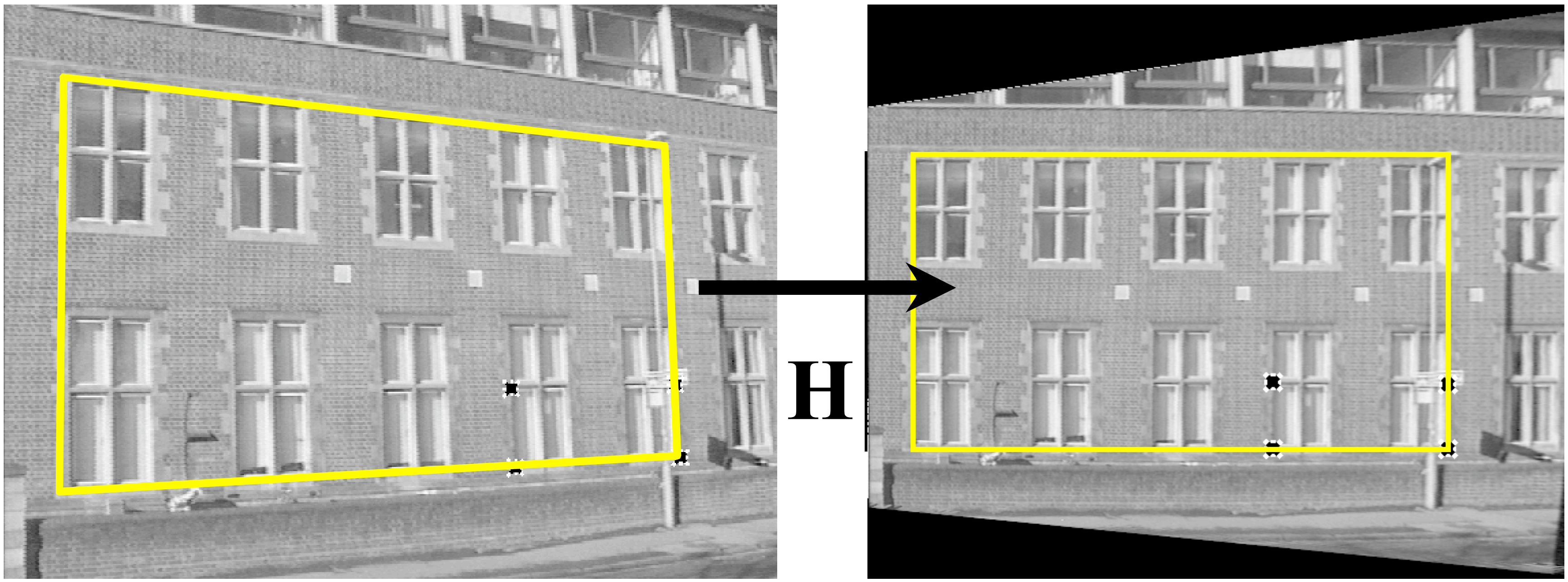
Mosaicing and Stabilization

Robert Collins
CSE486, Penn State

Recall: Planar Projection



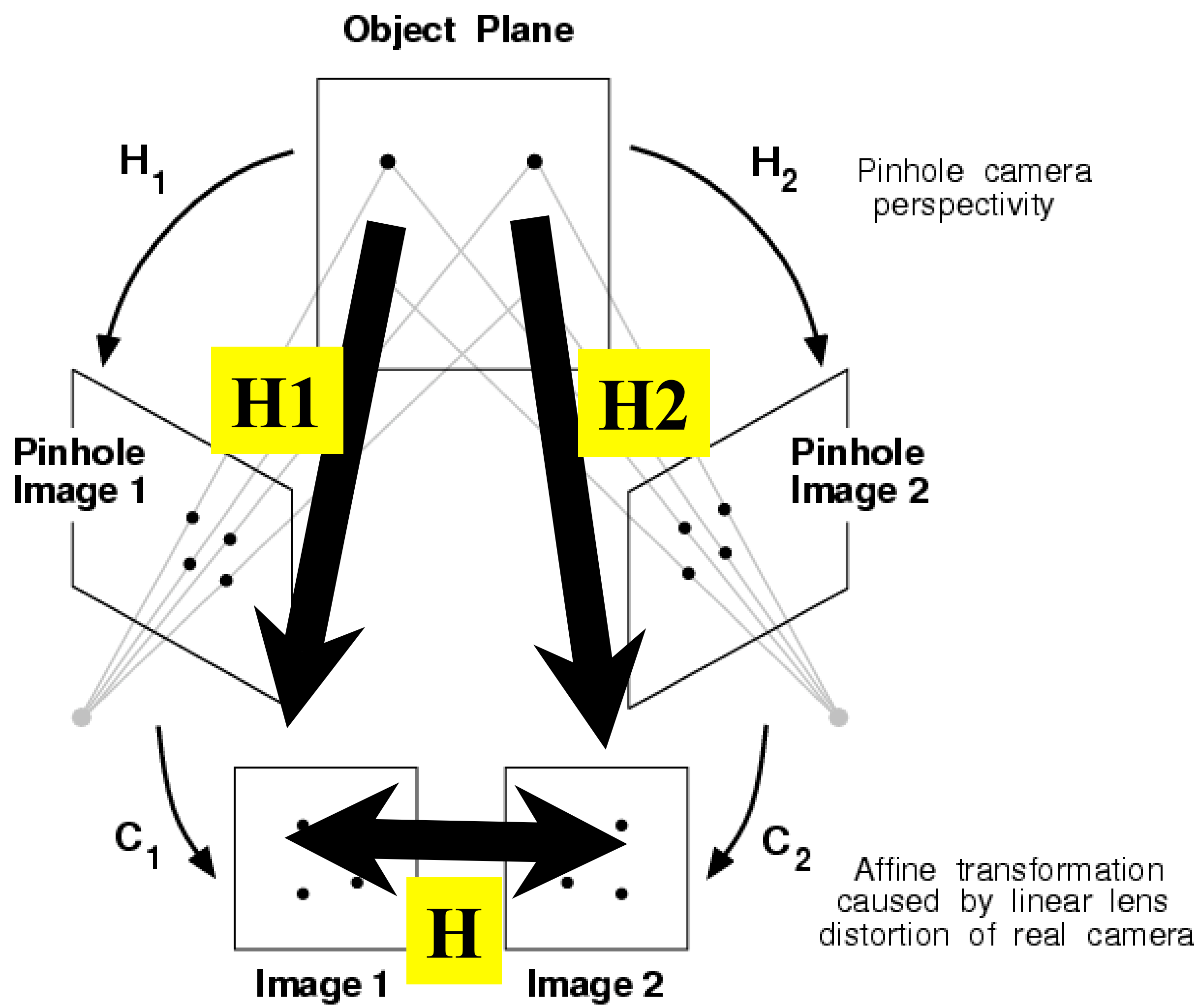
Recall: Projective (un)Warping



from Hartley & Zisserman

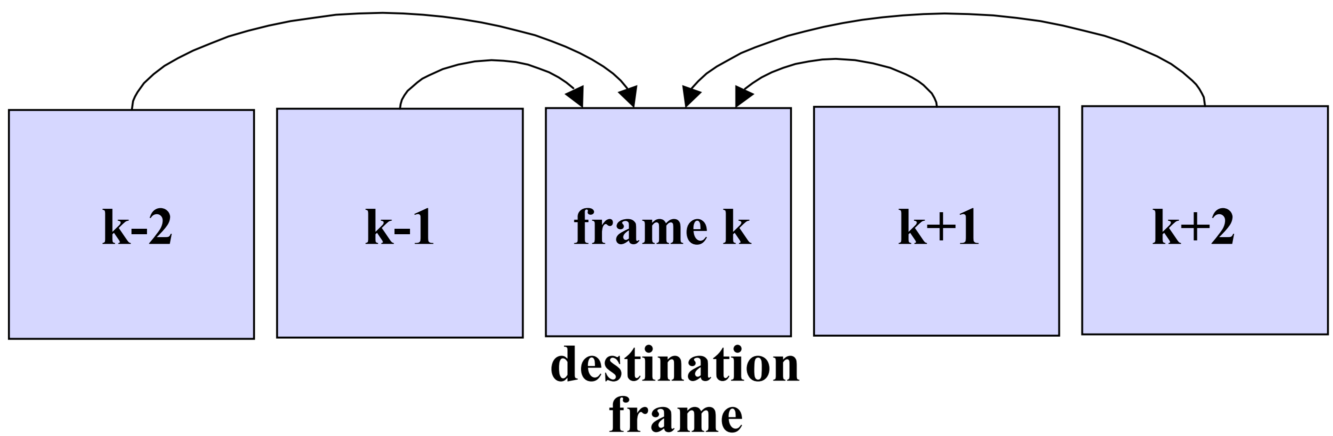
Source Image **Destination image**

Recall : Planar Projection



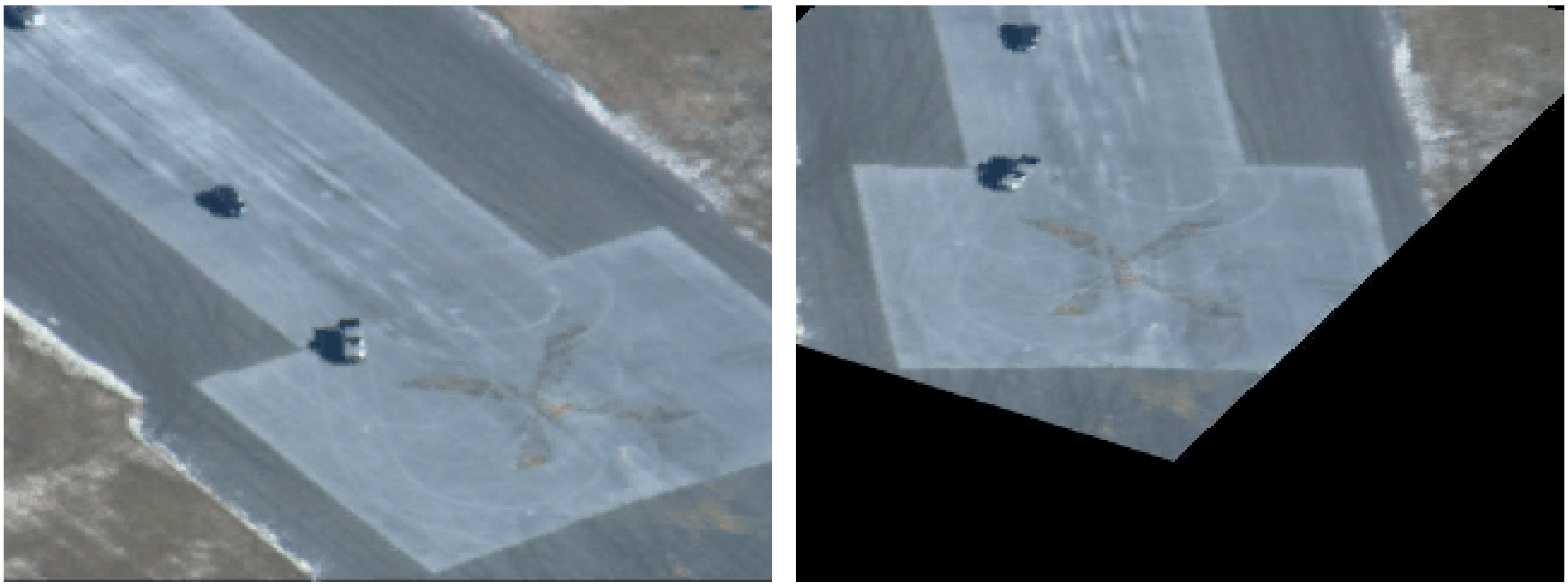
Applications: Stabilization

Given a sequence of video frames, warp them into a common image coordinate system.



This "stabilizes" the video to appear as if the camera is not moving.

Stabilization Example

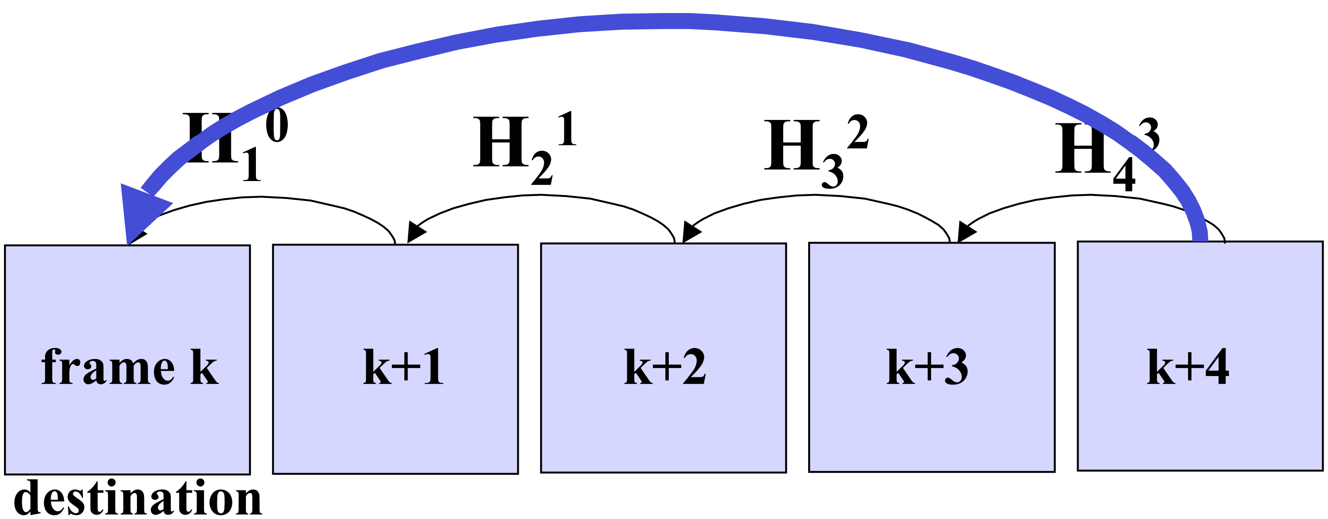


VIVID project

Stabilization by Chaining

What if the reference image does not overlap with all the source images? As long as there are pairwise overlaps, we can chain (compose) pairwise homographies.

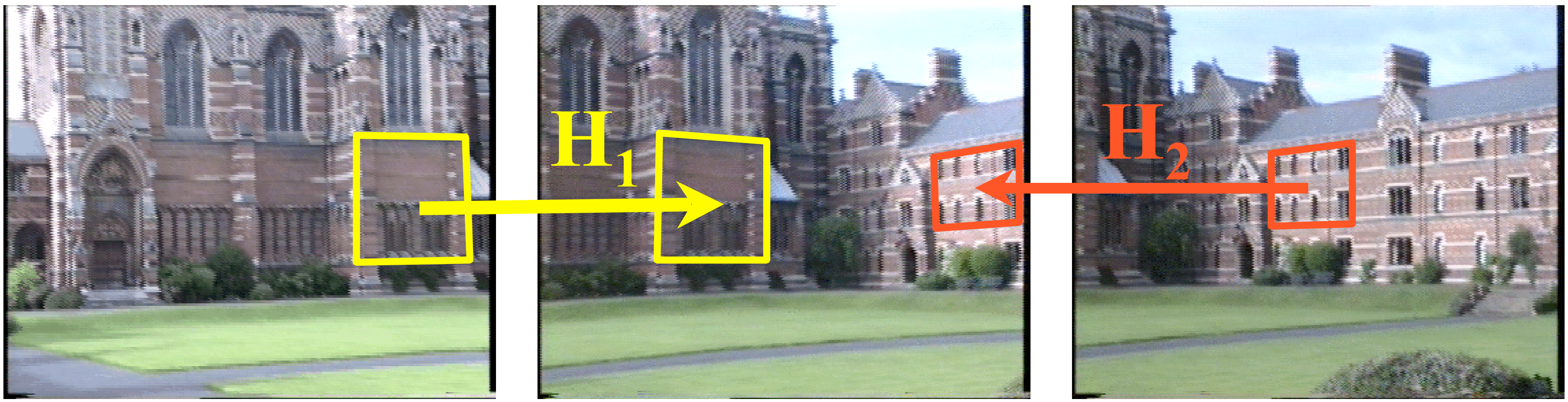
$$H_4^0 = H_1^0 * H_2^1 * H_3^2 * H_4^3$$



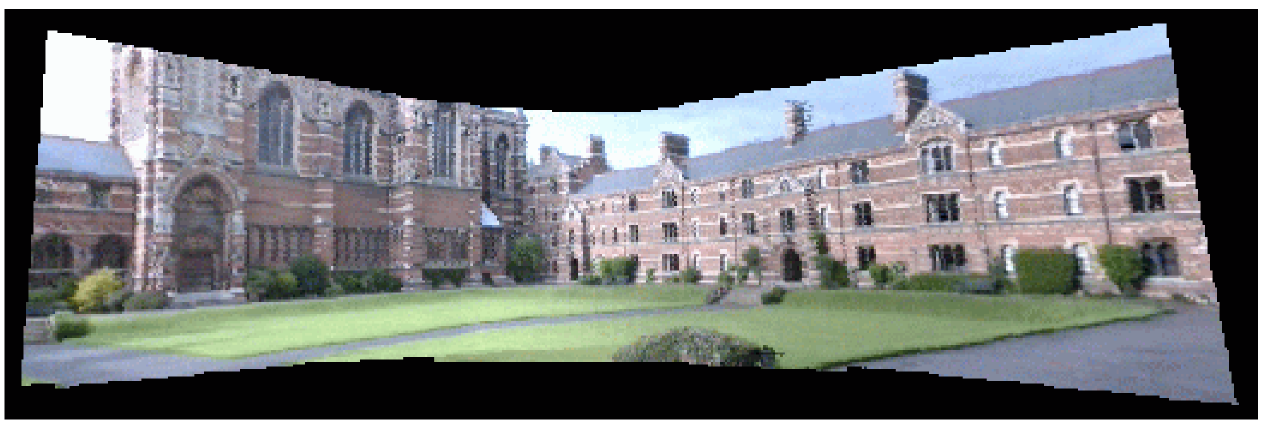
Not recommended for long sequences, as alignment errors accumulate over time.

Applications: Mosaicing

Source 1 | Destination image | Source 2



from Hartley & Zisserman



Mosaic

Note on Planar Mosaicing

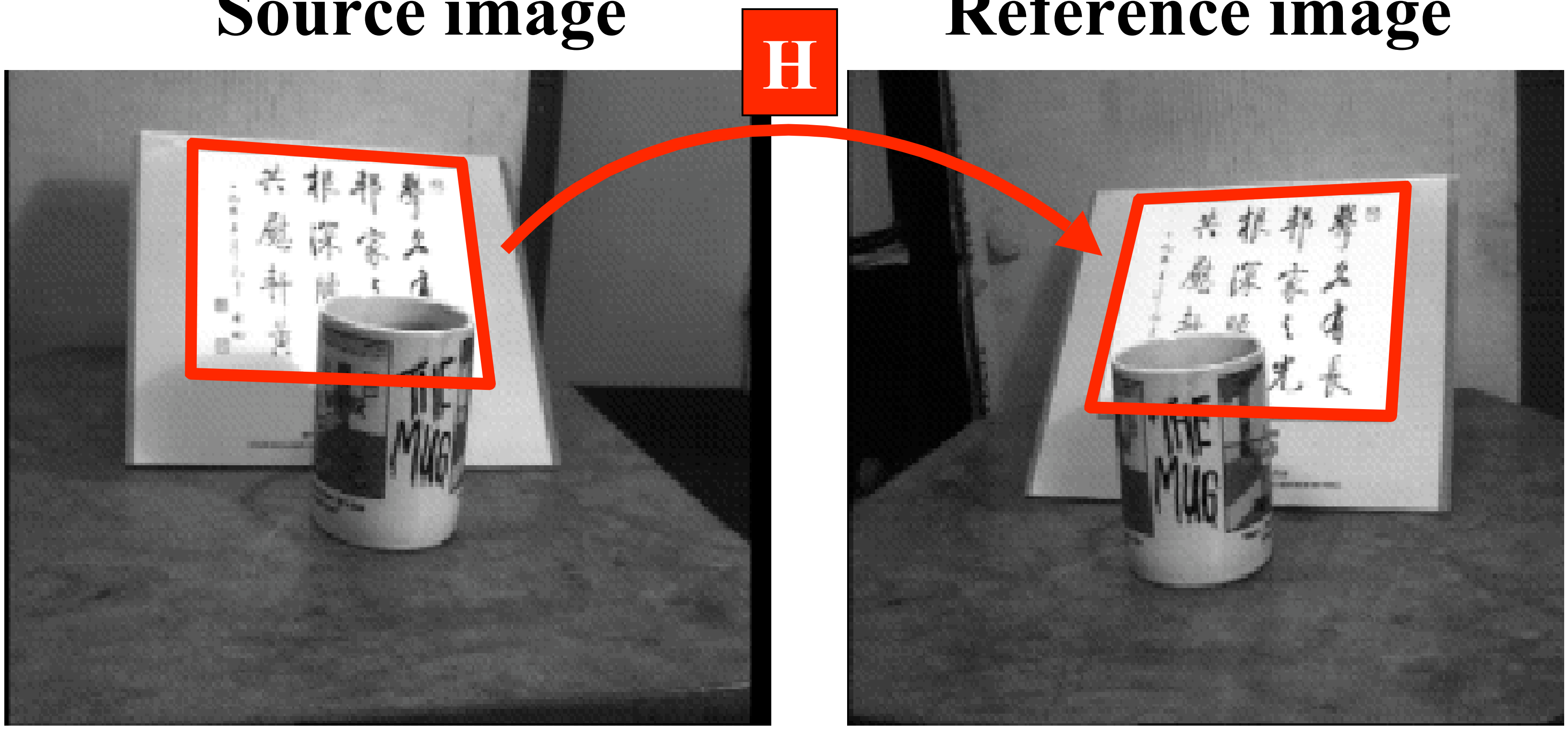
Assumes scene is roughly planar.

What if scene isn't planar? Alignment will not be good if significant 3D relief

→ "Ghosting"

Ghosting Example

Source image **Reference image**



Ghosting Example (cont)

Mosaic

Mosaics from Rotating Cameras

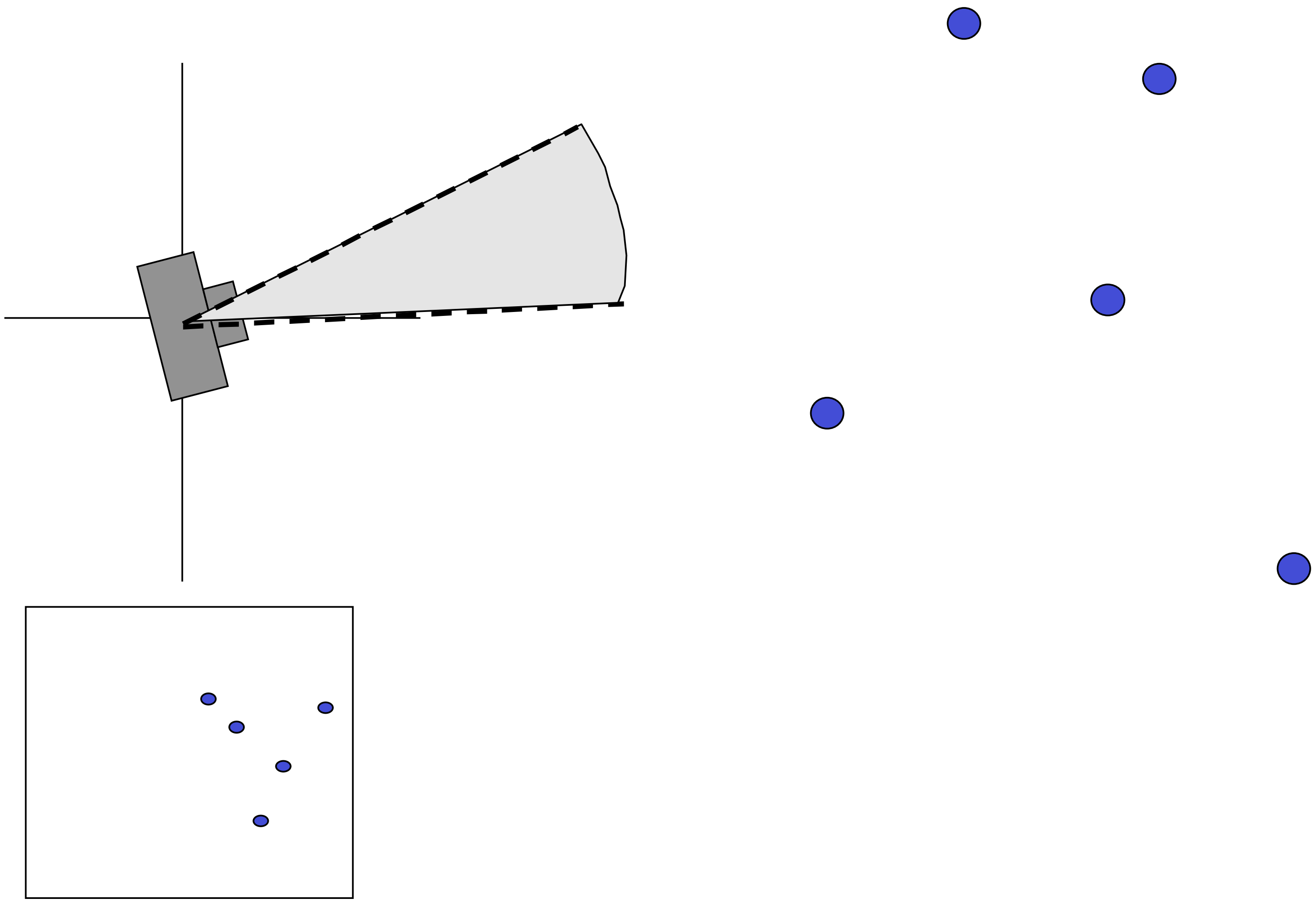
However, there is a mitigating factor in regards to ghosting…

Images taken from a rotating camera are related by a 2D homography…

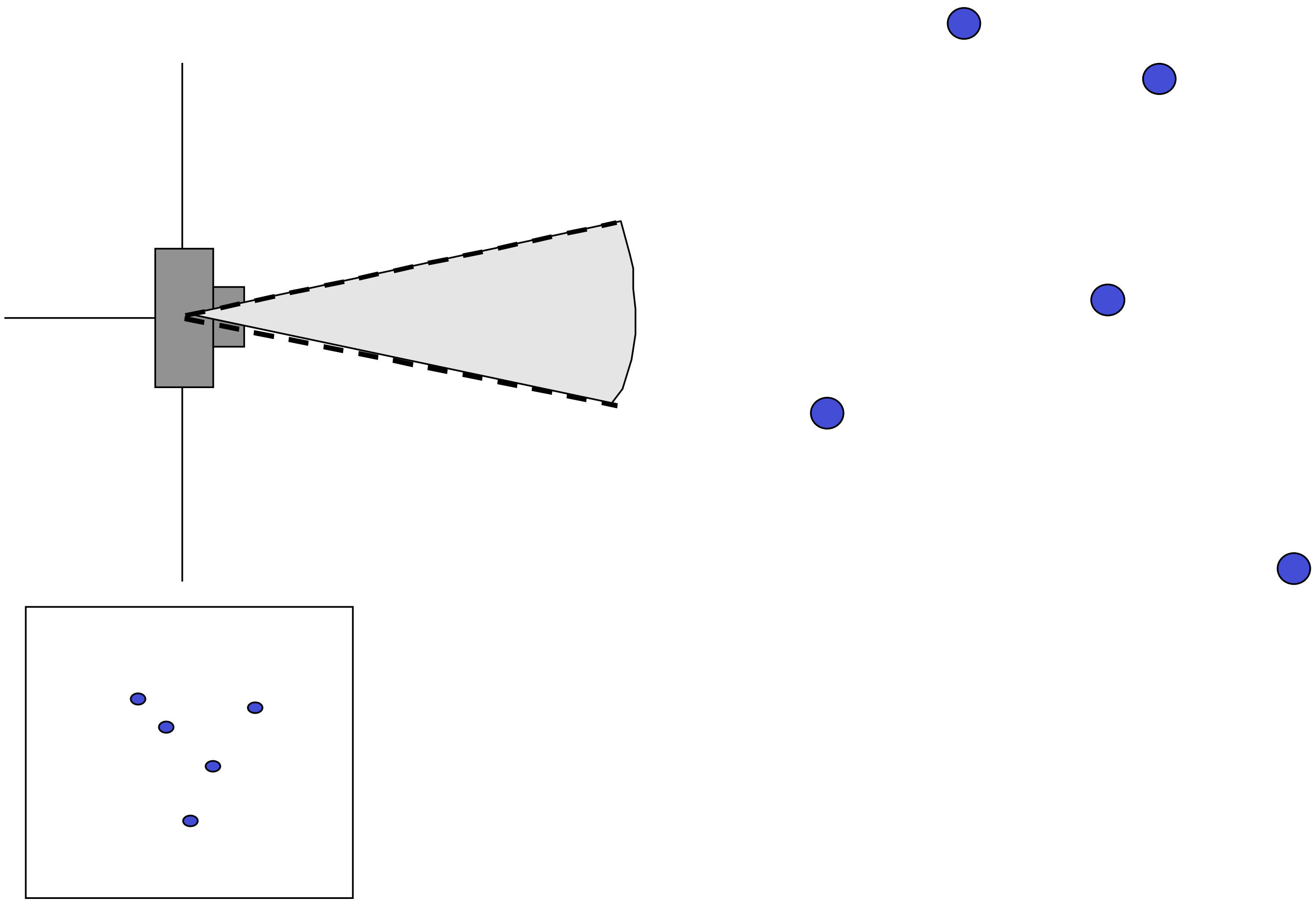
<u>regardless of scene structure!</u>

Robert Collins
CSE486, Penn State

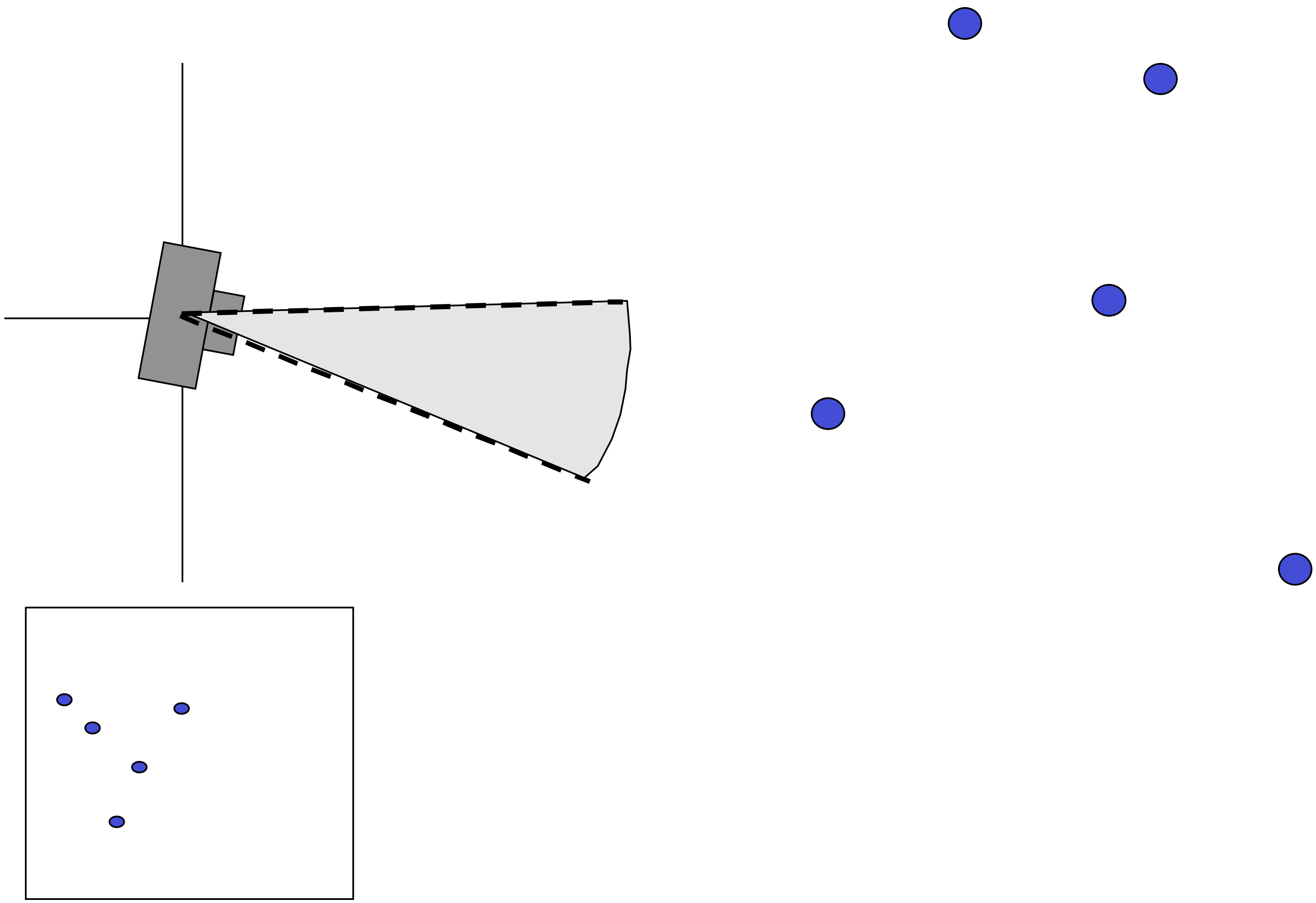
Rotating Camera (top-down view)



Rotating Camera (top-down view)

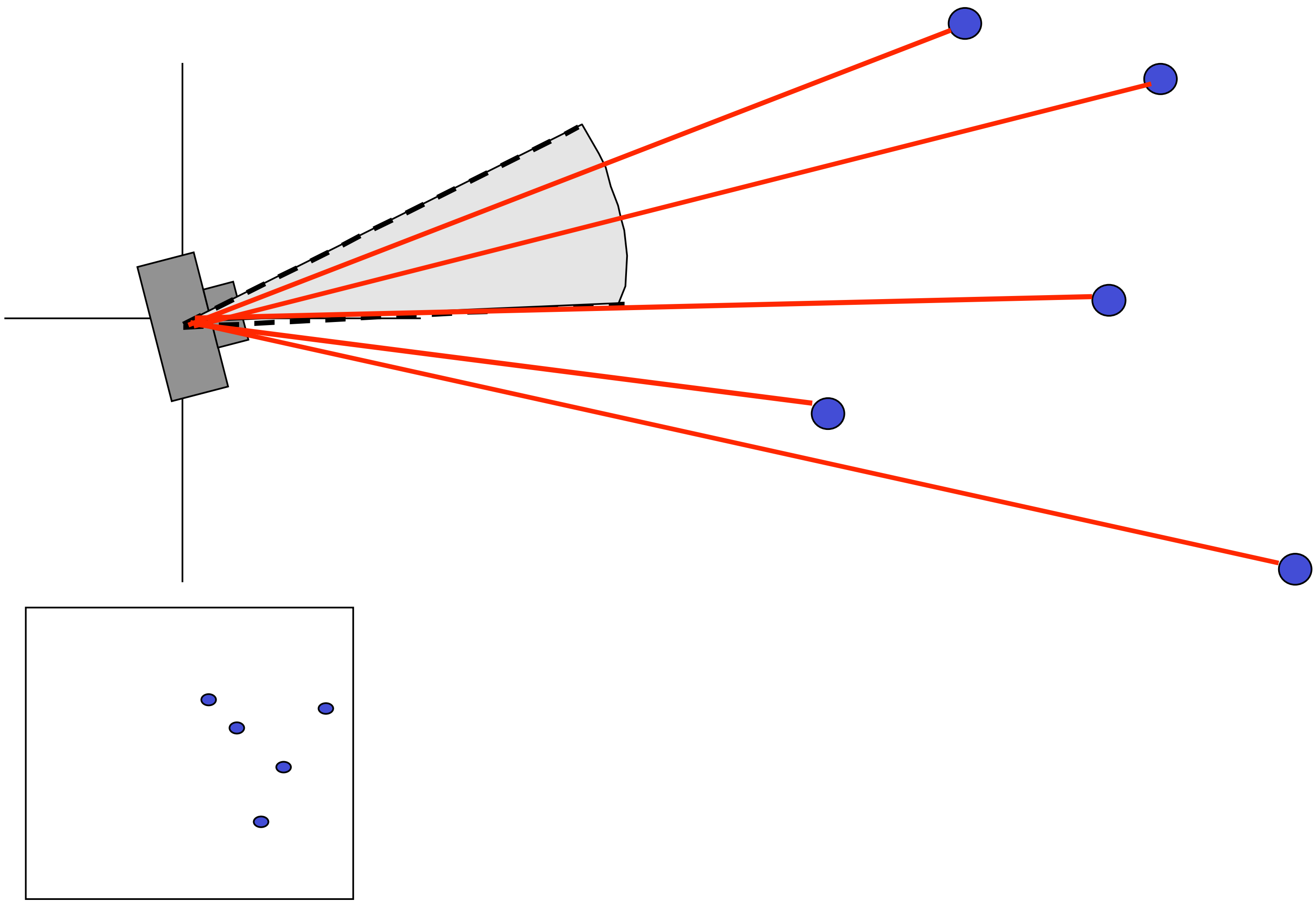


Rotating Camera (top-down view)



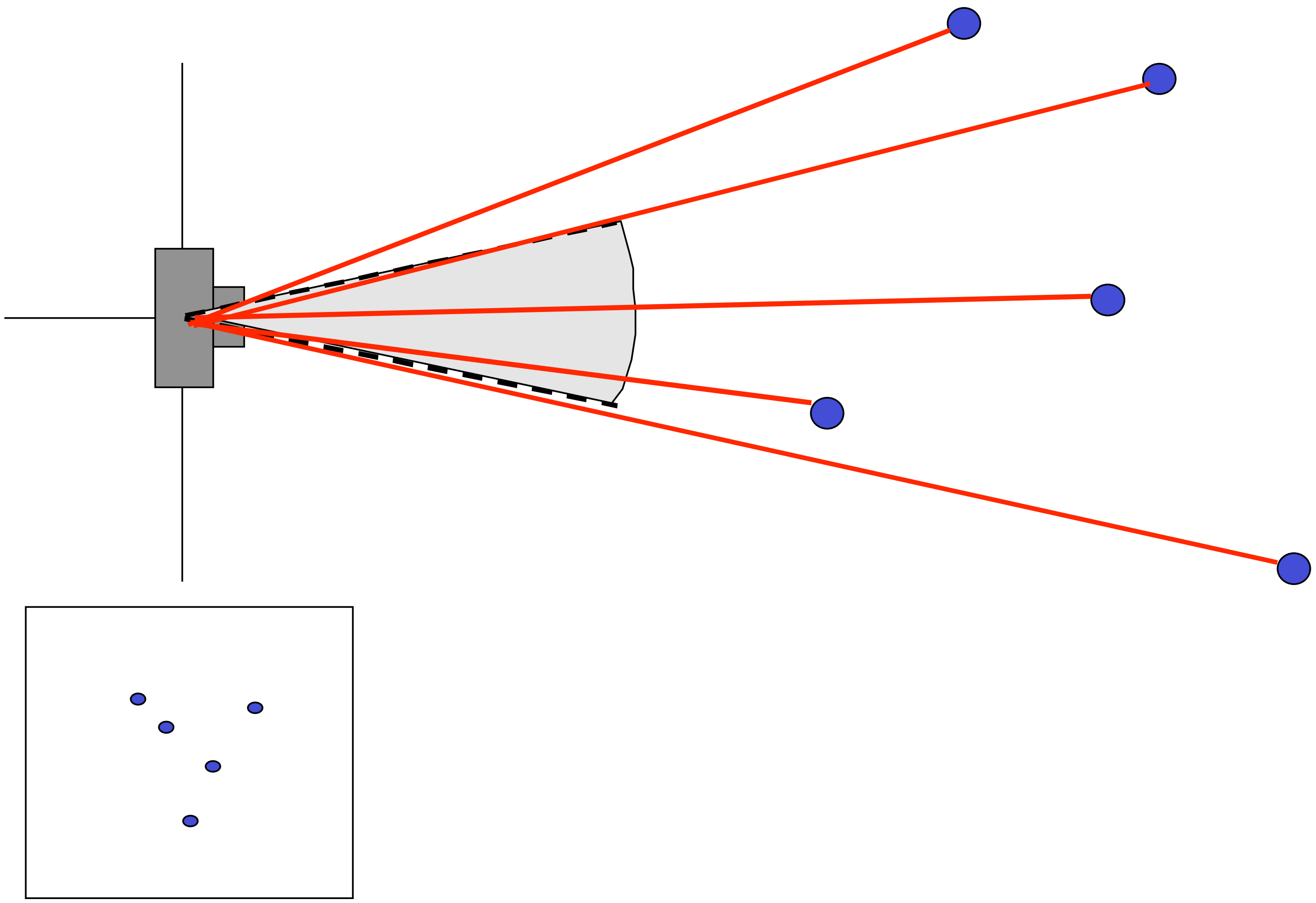
Rotating Camera (top-down view)

Rays in camera coord system are invariant!



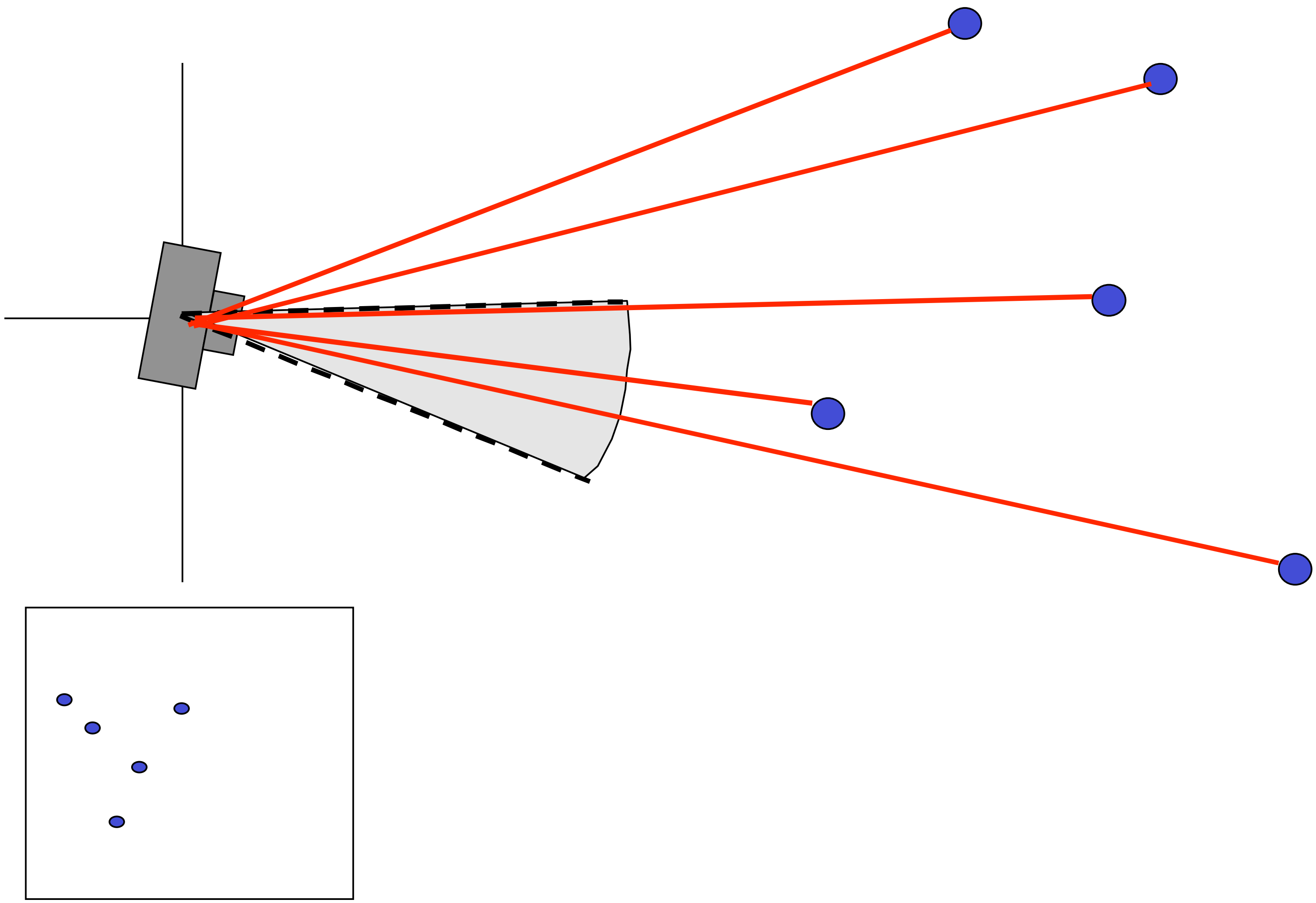
Rotating Camera (top-down view)

Rays in camera coord system are invariant!



Rotating Camera (top-down view)

Rays in camera coord system are invariant!



Special Case : Rotating Camera

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \sim \overset{\text{Internal params}}{\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ 0 & 0 & 1 \end{bmatrix}} \overset{\text{Projection}}{\begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}} \overset{\text{Relative R,T}}{\begin{bmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

Relative Rotation of camera

Translation is 0
This is important!

Special Case : Rotating Camera

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \sim \underbrace{\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ 0 & 0 & 1 \end{bmatrix}}_{\text{Internal params}} \underbrace{\begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}}_{\text{Projection}} \underbrace{\begin{bmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}}_{\text{Relative R,T}} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \sim \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} f & 0 & 0 \\ 0 & f & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \sim \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Robert Collins
CSE486, Penn State

Relations among Images Taken by Rotating Camera

Image 1
$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \sim \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Same ray!

Image 2
$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} \sim \begin{bmatrix} h'_{11} & h'_{12} & h'_{13} \\ h'_{21} & h'_{22} & h'_{23} \\ h'_{31} & h'_{32} & h'_{33} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

$$\boxed{\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \sim \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{bmatrix} h'_{11} & h'_{12} & h'_{13} \\ h'_{21} & h'_{22} & h'_{23} \\ h'_{31} & h'_{32} & h'_{33} \end{bmatrix}^{-1} \begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix}}$$

Robert Collins
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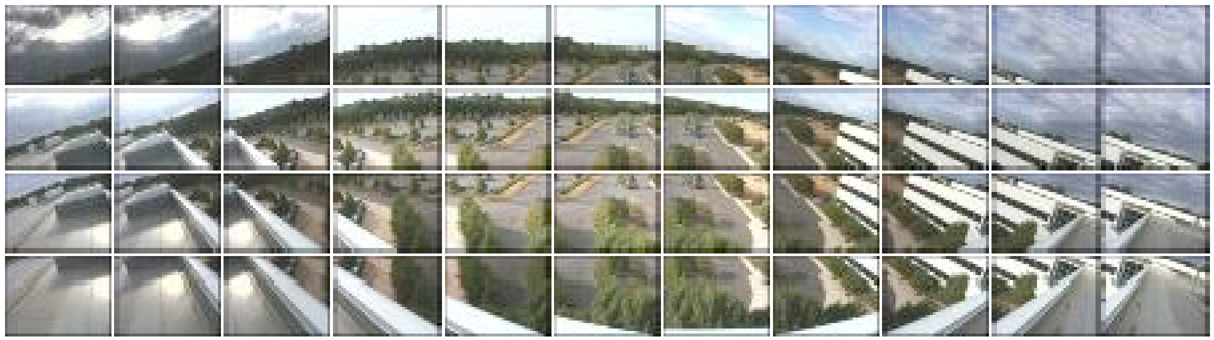
Mosaicing Example

Original Images (from a pan/tilt camera)



Panoramic (Mosaic) View

One more detail: Blending!

Approaches to Blending

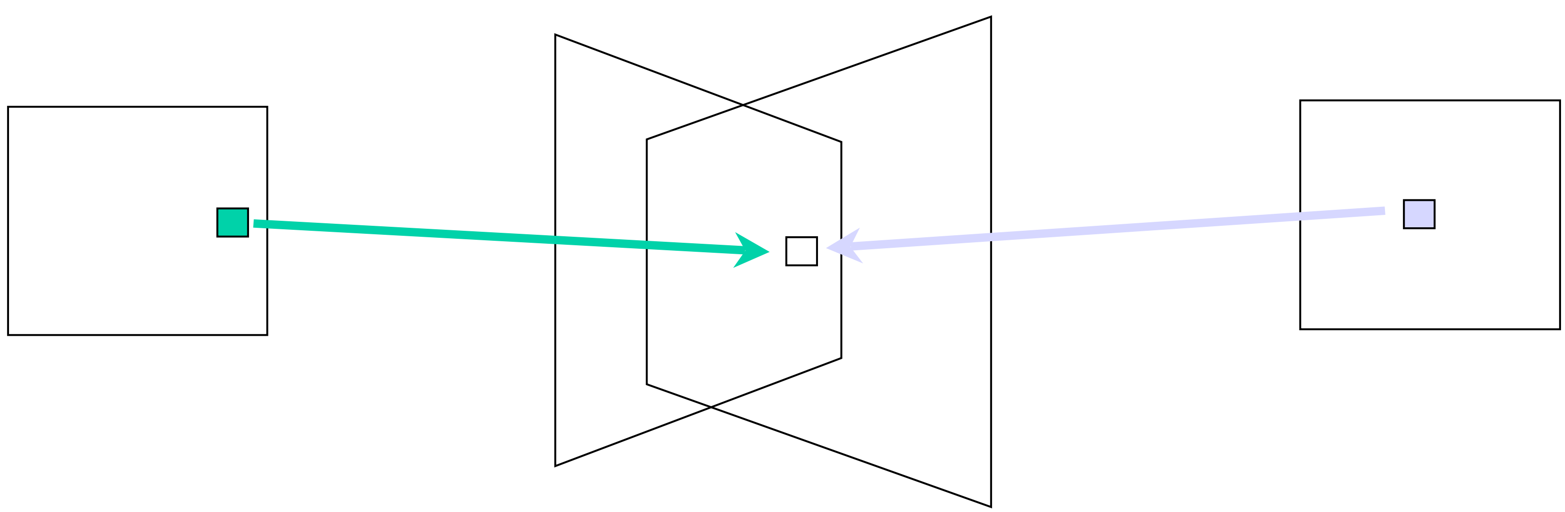
How to combine colors in area of overlap?

1) Straight averaging $\mathbf{P = (P_1 + P_2) / 2}$

2) Feathering $\mathbf{P = (w_1 * P_1 + w_2 * P_2) / (w_1 + w_2)}$

With w_i being distance from image border

3) Equalize intensity statistics (gain, offset)



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Before and After Blending

360 Degree Panoramas?

Problem: Can’t just choose a reference image to map all other images to.

Solution: Use cylindrical or spherical mosaic surface rather than a plane.

Panorama Input images

Sarnoff

Spherical Panorama Result

Sarnoff

Panorama Unwarped

Sarnoff

Quicktime VR

This example from www.panoguide.com/gallery/

Also big list at http://www.multimedialibrary.com/diana/qtvr_sites.asp

Quicktime VR

Quicktime VR

This example from www.ems.psu.edu/~fraser/qtvr/