

Panoramas

CS 178, Spring 2010



Marc Levoy
Computer Science Department
Stanford University

What is a panorama?

- ◆ a wider-angle image than a normal camera can capture
- ◆ any image stitched from overlapping photographs
- ◆ an extreme aspect ratio on a normal shot

Outline

- ◆ capturing panoramas
- ◆ stitching together a panorama
- ◆ perspective versus cylindrical projection

Panoramic cameras



flatback panoramic camera



swing-lens panoramic camera



SLR on panning clamp



motorized pan-tilt head © Marc Levoy

Swing-lens panoramic images



San Francisco in ruins, 1906



101 Ranch, Oklahoma, circa 1920

Panoramic cameras



to avoid parallax errors,
rotate around center of
perspective

flatback panoramic camera



swing-lens panoramic camera



SLR on panning clamp



motorized pan-tilt head © Marc Levoy

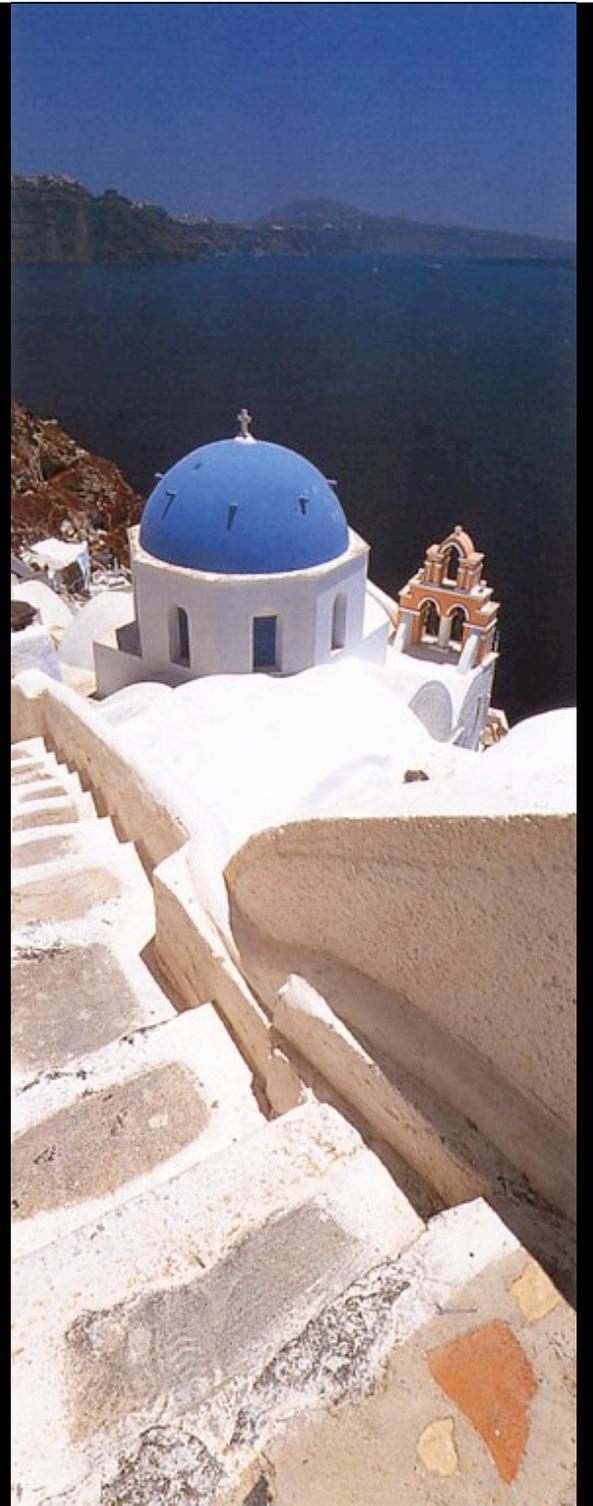


Lee Frost, Val D'Orcia, Tuscany, Italy



Lee Frost, Volubilis, Morocco

Lee Frost,
Vertical Panoramas,
Santorini





Matthew Scott, Cuernos del Paine, Chile



gigapan.org, Scanning Electron Micrograph (SEM) of barnacle



gigapan.org, Scanning Electron Micrograph (SEM) of barnacle

Stitching images together to make a mosaic

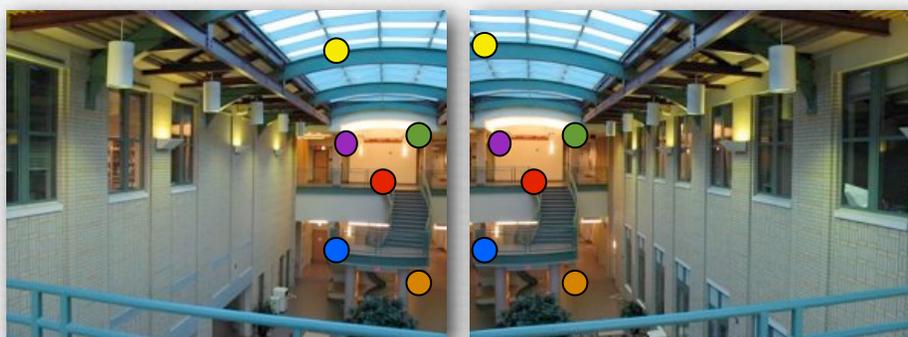


Stitching images together to make a mosaic



- ◆ given a set of images that should stitch together
 - by rotating the camera around its center of perspective
- ◆ step 1: find corresponding features in a pair of image
- ◆ step 2: compute transformation from 2nd to 1st image
- ◆ step 3: warp 2nd image so it overlays 1st image
- ◆ step 4: blend images where they overlap one another
- ◆ repeat for 3rd image and mosaic of first two, etc.

Stitching images together to make a mosaic



Take CS 223B:
Computer Vision (Win)



- ◆ given a set of images that should stitch together
 - by rotating the camera around its center
- ◆ step 1: find corresponding features in pairs of images
- ◆ step 2: compute transformation from 2nd to 1st image
- ◆ step 3: warp 2nd image so it overlays 1st image
- ◆ step 4: blend images where they overlap
- ◆ repeat for 3rd image and mosaic of first two

Take CS 148:
Introduction to Computer
Graphics (Aut)

Also CS 448A:
Computational
Photography (Win 2012)

What kind of transformation do we need?



translation?

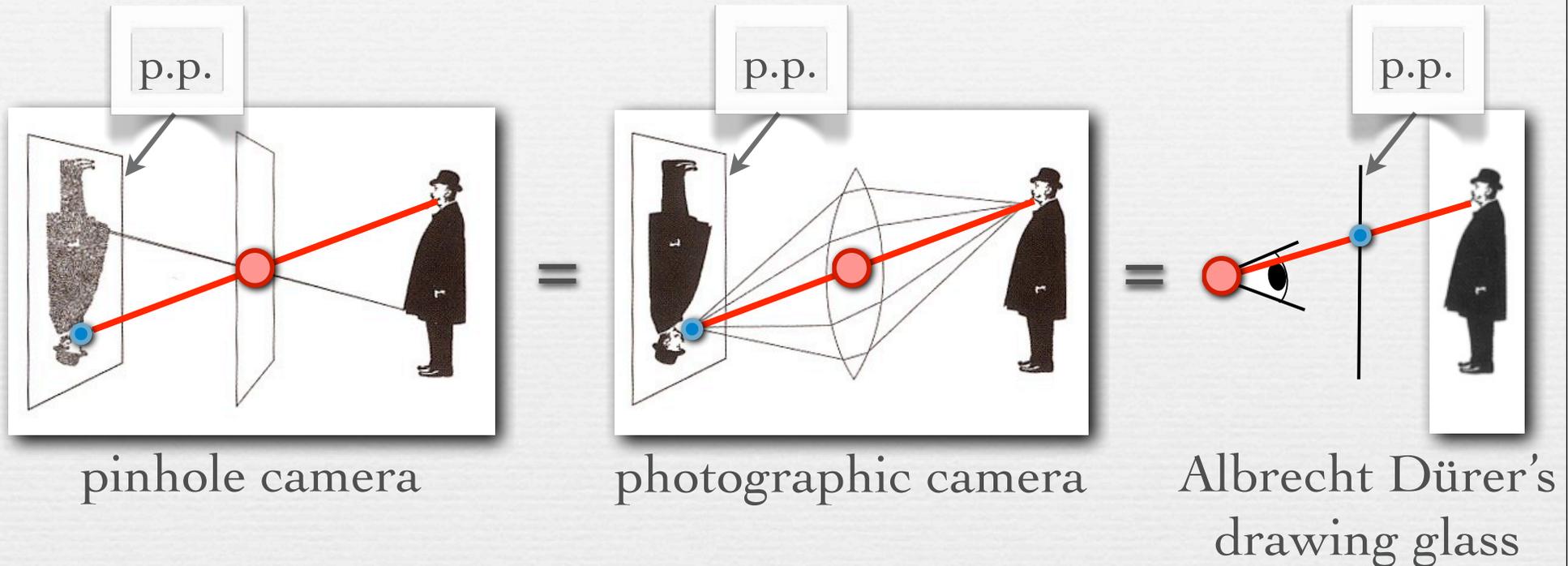


rotation?



perspective!

Quick review of perspective projection



● = center of perspective (c.p.)

● = projection of feature in scene onto picture plane (p.p.)

- ◆ these three image formation methods will produce the same perspective view on the p.p. (except for the size of the view)
 - all that matters is position of c.p. and orientation of p.p.

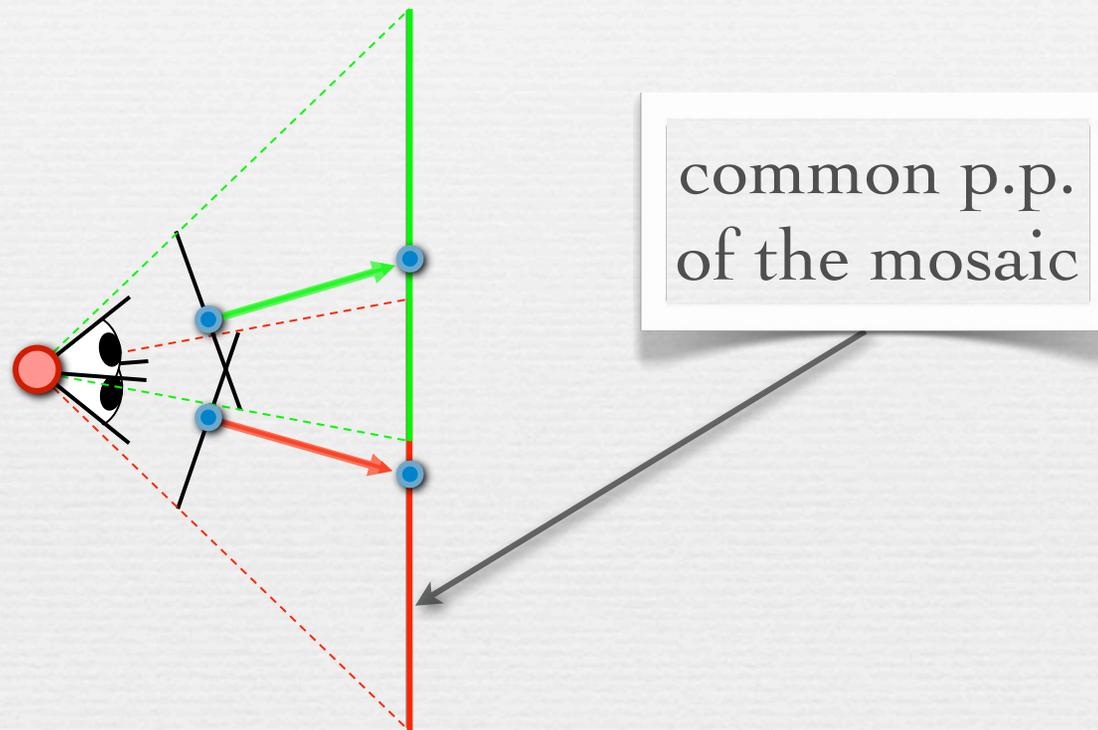
Reprojecting an image onto a different picture plane



the sidewalk art of Julian Beever

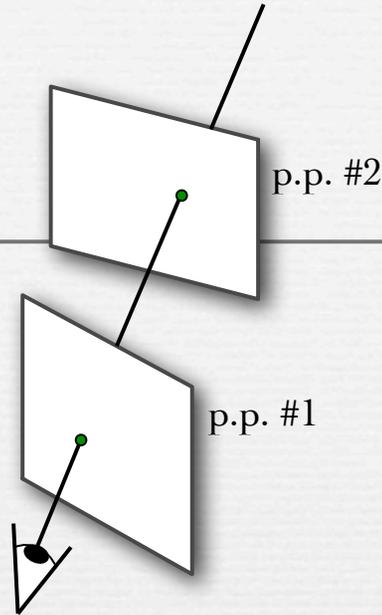
- ◆ the view on any picture plane can be projected onto any other plane in 3D without changing its appearance as seen from a common center of projection

Reprojecting panoramic images to a common picture plane



- ◆ the common picture plane of the mosaic replaces having had a wide-angle (non-fish-eye) camera in the first place

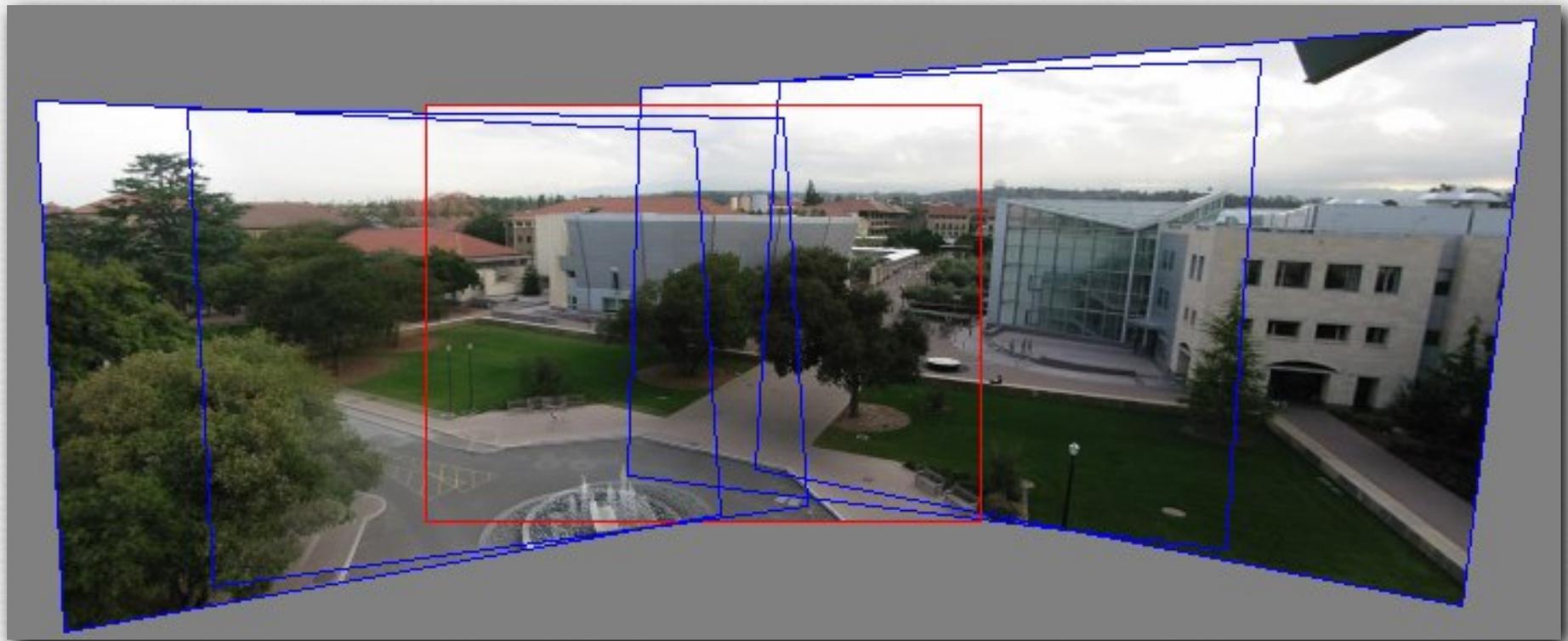
Homography



In class I said a 4x4 matrix. Actually, since the positions of features in an image can be fully specified by their x,y positions, the perspective warp (homography) can be treated as a $2D \rightarrow 2D$ mapping and described using a 3×3 matrix transformation, where the positions are given as $3D$ homogeneous coordinates. In other words, output position $[x', y', w']^T = M \times [x, y, 1]^T$, where M is a 3×3 matrix. Want to learn more about this? Look at this CS 248 lecture: <http://graphics.stanford.edu/courses/cs248-08/texturing/texturing.html>.

- ◆ perspective mapping between two p.p.'s using the same center of projection is called a *homography*
 - input and output x,y positions are related by a 3×3 matrix

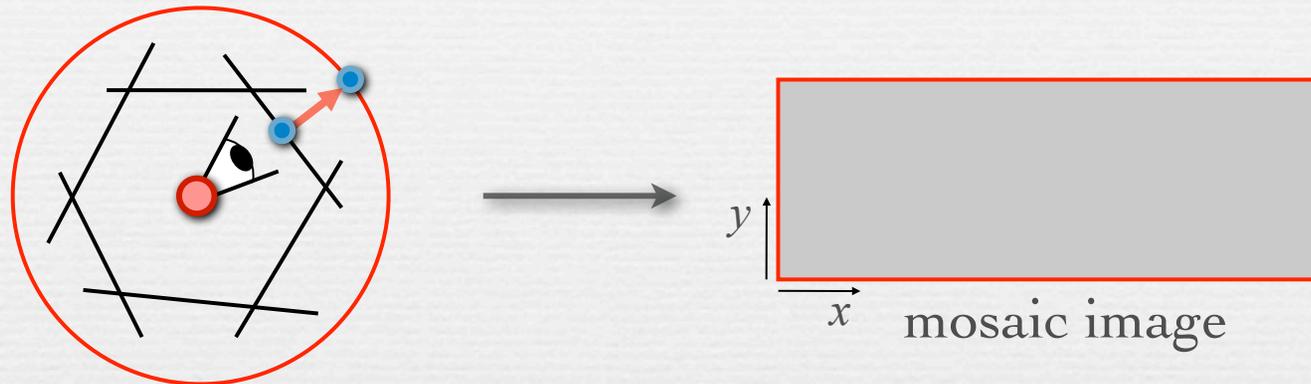
Summary of perspective stitching



- ◆ pick one image, typically the central view (red outline)
- ◆ warp the others to its plane
- ◆ blend

Cylindrical panoramas

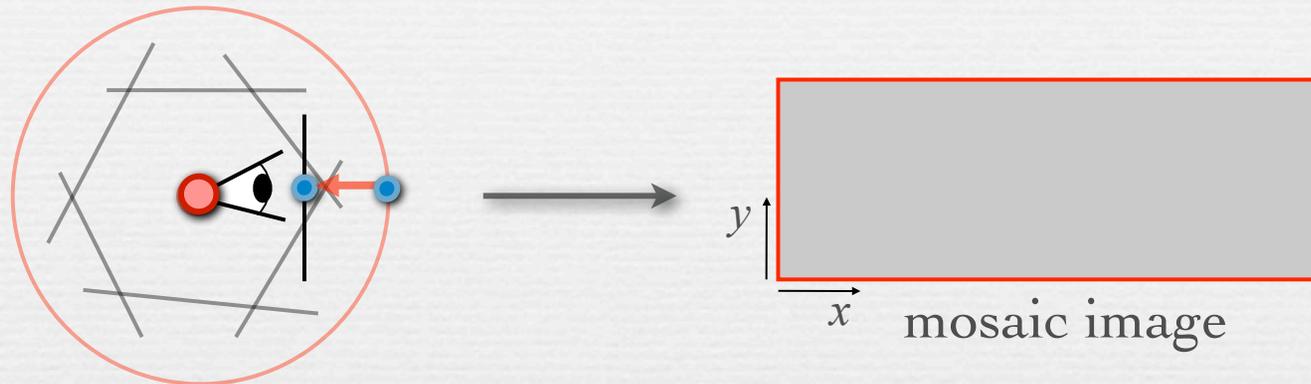
- ◆ What if you want a 360° panorama?



- ◆ project each image onto a cylinder
- ◆ a cylindrical image can be stored as a rectangular image

Cylindrical panoramas

- ◆ What if you want a 360° panorama?



- ◆ project each image onto a cylinder
- ◆ a cylindrical image can be stored as a rectangular image
- ◆ to view without distortion, reproject a portion of the cylinder onto a picture plane representing the display screen
 - if your FOV is narrow, this view won't be too distorted

Example

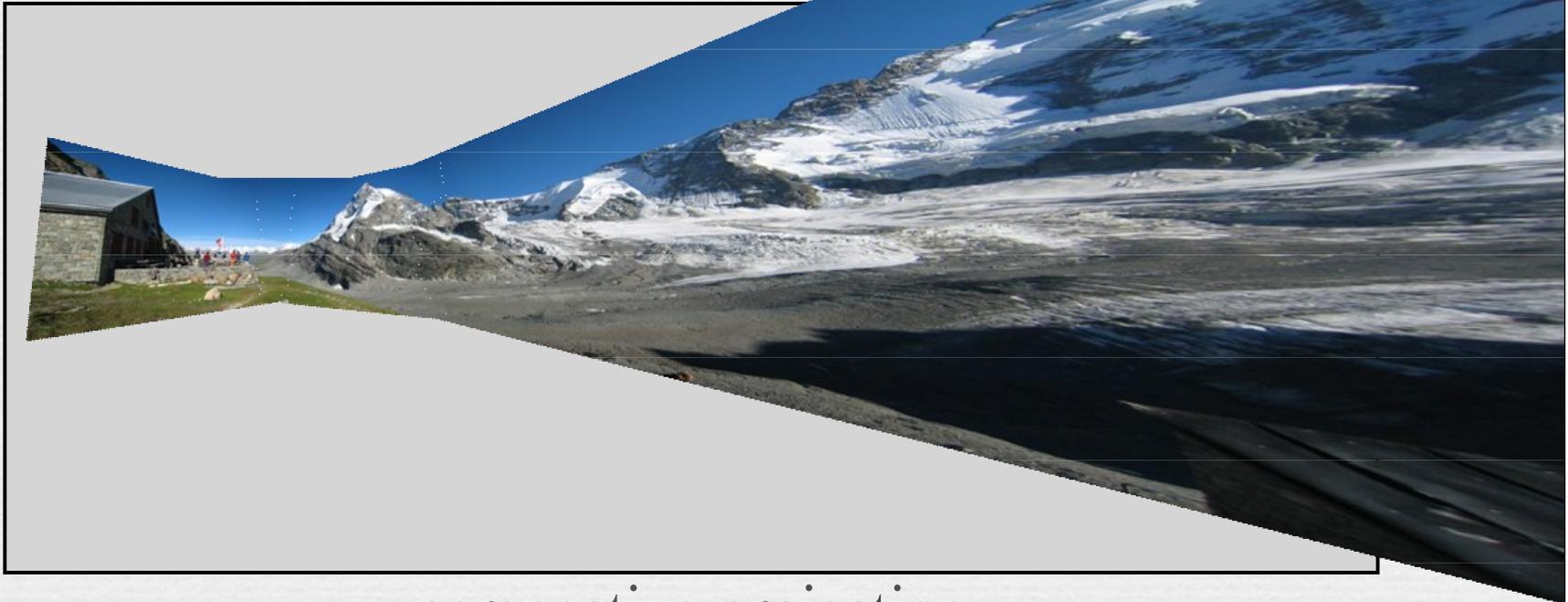


common
picture
plane of
mosaic
image



perspective projection

Using 4 shots instead of 3



perspective projection

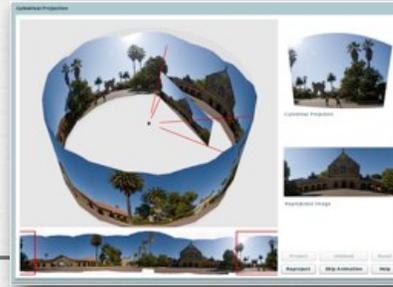
Back to 3 shots



surface of
cylinder

cylindrical projection

Back to 3 shots



(FLASH DEMO)

<http://graphics.stanford.edu/courses/cs178/applets/projection.html>

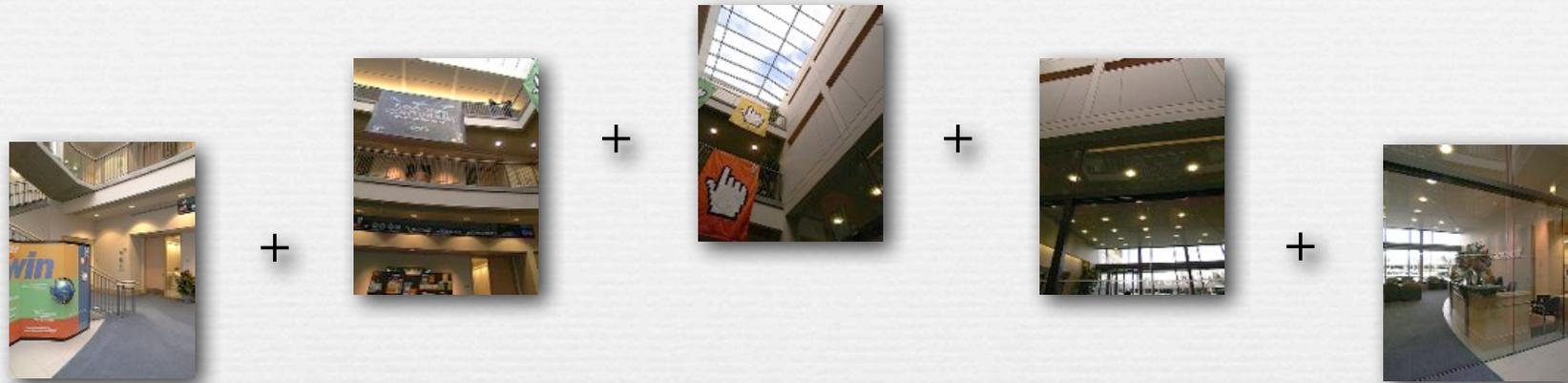


surface of
cylinder



cylindrical projection

Spherical panoramas



- ◆ projections are to a sphere instead of a cylinder
- ◆ can't store as rectangular image without distortion

Recap

- ◆ panoramas can be captured by a camera with a wide planar back, a cylindrical back and a moving slit, or a rotating camera
 - rotate around the center of perspective to avoid *parallax errors*
- ◆ to assemble panoramas from a rotating camera, use corresponding features to compute a *perspective warp* that projects the images to a *common picture plane*, then blend them together
- ◆ for very wide angle or 360° panoramas, project the images to a *common cylindrical surface*, which can be stored as an ordinary (wide) rectangular image
 - reproject them to a picture plane for display
- ◆ spherical panoramas are possible, but cannot be stored as rectangular images without distortion

Questions?

Slide credits

- ◆ Fredo Durand
 - ◆ Alyosha Efros
 - ◆ Steve Seitz
 - ◆ Rick Szeliski
-
- ◆ Frost, Lee, *Panoramic Photography*, F+W Publications, 2005.

calvin and HOBBS

WATTERSON

