Announcements

- Project 2
  - Out today
  - Sign up for a panorama kit ASAP!
    - best slots (weekend) go quickly...

Mosaics part 2

VR Seattle: http://www.vrseattle.com/
Full screen panoramas (cubic): http://www.panoramas.dk/
Mars: http://www.panoramas.dk/fullscreen3/f2_mars97.html

Today's Readings

- Szeliski and Shum paper (sections 1 and 2, skim the rest)
  - http://www.cs.washington.edu/education/courses/455/08wi/readings/szeliskiShum97.pdf

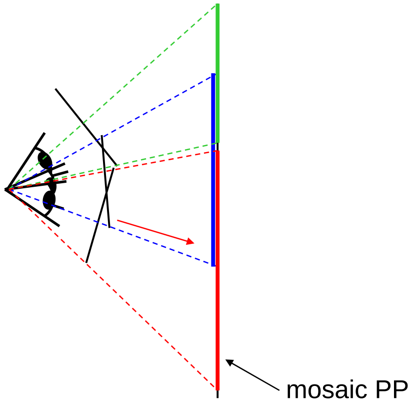
Project 2

1. Take pictures on a tripod (or handheld)
2. Warp to spherical coordinates
3. Extract features
4. Align neighboring pairs using RANSAC
5. Write out list of neighboring translations
6. Correct for drift
7. Read in warped images and blend them
8. Crop the result and import into a viewer

Roughly based on **Autostitch**

- By Matthew Brown and David Lowe
- http://www.cs.ubc.ca/~mbrown/autostitch/autostitch.html

Image reprojection



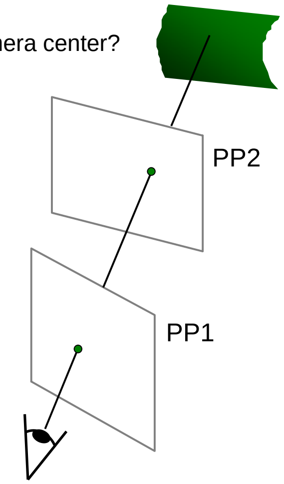
The mosaic has a natural interpretation in 3D

- The images are reprojected onto a common plane
- The mosaic is formed on this plane

Image reprojection

Basic question

- How to relate two images from the same camera center?
  - how to map a pixel from PP1 to PP2

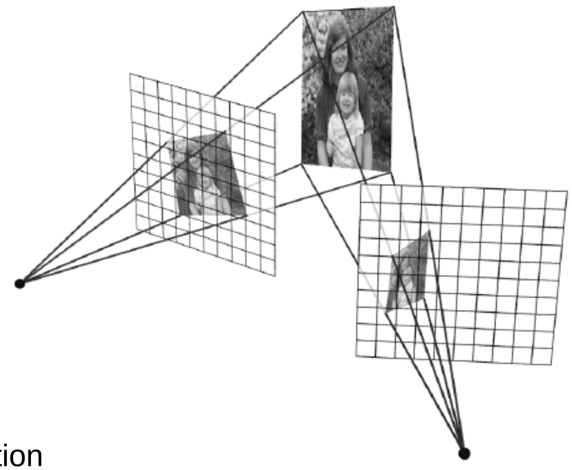


Answer

- Cast a ray through each pixel in PP1
- Draw the pixel where that ray intersects PP2

Don't need to know what's in the scene!

Image reprojection



Observation

- Rather than thinking of this as a 3D reprojection, think of it as a 2D image warp from one image to another

Homographies

Perspective projection of a plane

- Lots of names for this:
  - **homography**, texture-map, colineation, planar projective map
- Modeled as a 2D warp using homogeneous coordinates

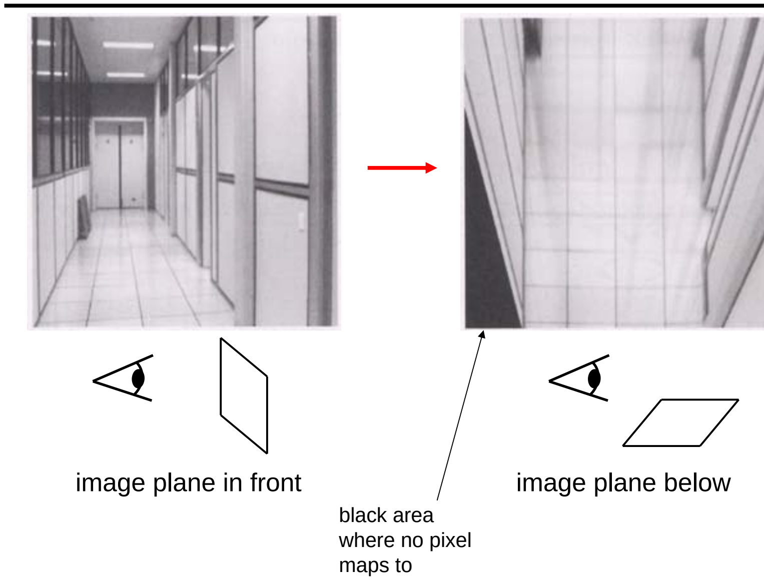
$$\begin{bmatrix} wx' \\ wy' \\ w \end{bmatrix} = \begin{bmatrix} * & * & * \\ * & * & * \\ * & * & * \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

$$\mathbf{p'} \qquad \mathbf{H} \qquad \mathbf{p}$$

To apply a homography **H**

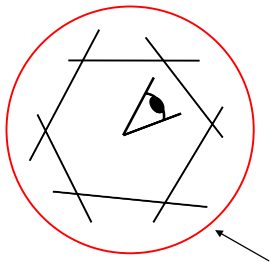
- Compute **p'** = **Hp** (regular matrix multiply)
- Convert **p'** from homogeneous to image coordinates
  - divide by w (third) coordinate

Image warping with homographies



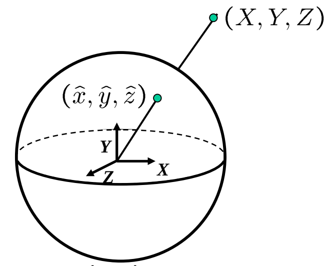
Panoramas

What if you want a 360° field of view?

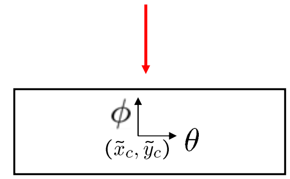


mosaic Projection Sphere

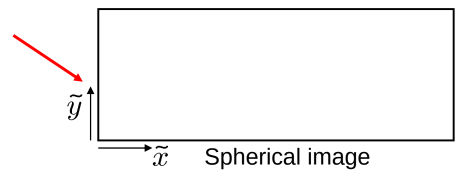
Spherical projection



unit sphere



unwrapped sphere



Spherical image

- Map 3D point (X,Y,Z) onto sphere

$$(\hat{x},\hat{y},\hat{z}) = \frac{1}{\sqrt{X^2+Y^2+Z^2}}(X,Y,Z)$$

- Convert to spherical coordinates

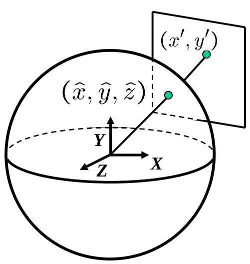
$$(sin\theta cos\phi, sin\phi, cos\theta cos\phi) = (\hat{x},\hat{y},\hat{z})$$

- Convert to spherical image coordinates

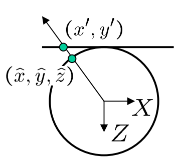
$$(\tilde{x},\tilde{y}) = (s\theta, s\phi) + (\tilde{x}_c,\tilde{y}_c)$$

  – s defines size of the final image
    » often convenient to set s = camera focal length

Spherical reprojection



side view

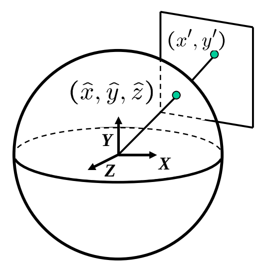


top-down view

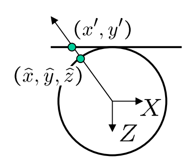
How to map sphere onto a flat image?

- $(\hat{x},\hat{y},\hat{z})$ to (x',y')

Spherical reprojection



side view



top-down view

How to map sphere onto a flat image?

- $(\hat{x},\hat{y},\hat{z})$ to (x',y')

– Use image projection matrix!
  – or use the version of projection that properly accounts for radial distortion, as discussed in projection slides. This is what you'll do for project 2.

Spherical reprojection

input **f = 200 (pixels)** **f = 400** **f = 800**

Map image to spherical coordinates

- need to know the focal length

Aligning spherical images

Suppose we rotate the camera by θ about the vertical axis

- How does this change the spherical image?

Aligning spherical images

Suppose we rotate the camera by θ about the vertical axis

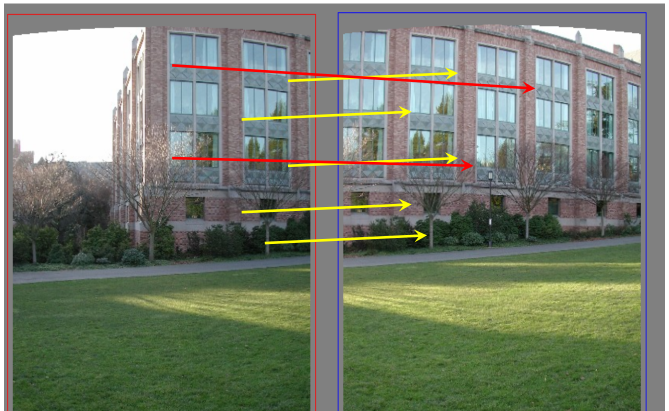
- How does this change the spherical image?
  - Translation by θ
- This means that we can align spherical images by translation

Spherical image stitching

What if you don't know the camera rotation?

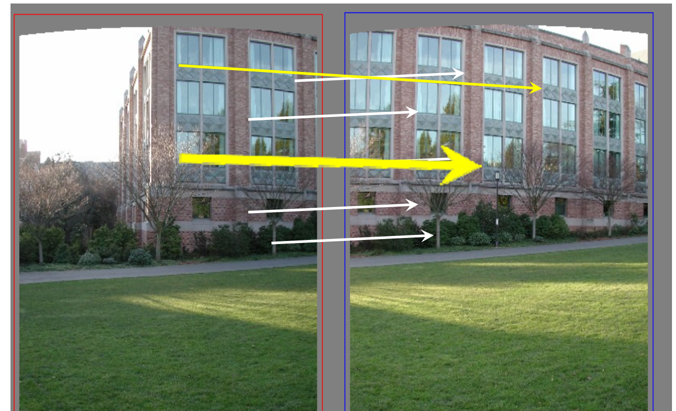
- Solve for the camera rotations
  - Note that a pan (rotation) of the camera is a **translation** of the sphere!
  - Use feature matching to solve for translations of spherical-warped images

Computing image translations



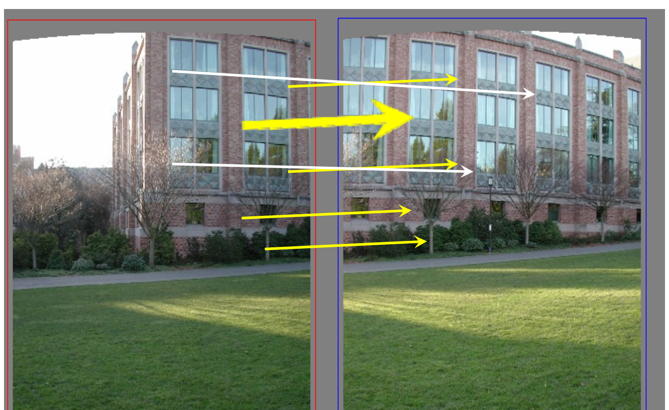
What do we do about the “bad” matches?

RAndom SAmple Consensus



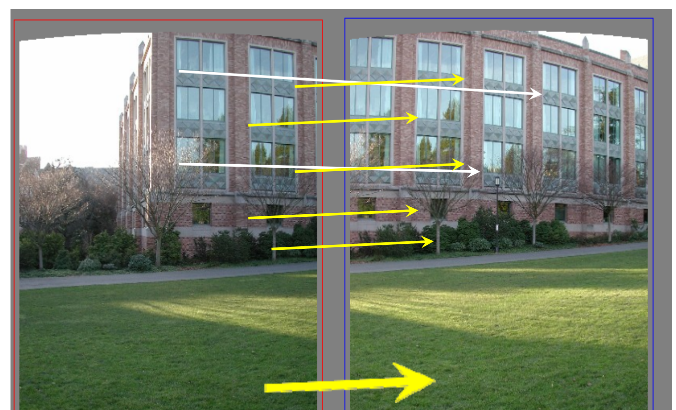
Select *one* match, count *inliers*
(in this case, only one)

RAndom SAmple Consensus



Select *one* match, count *inliers*
(4 inliers)

Least squares fit



Find “average” translation vector
for largest set of inliers

RANSAC

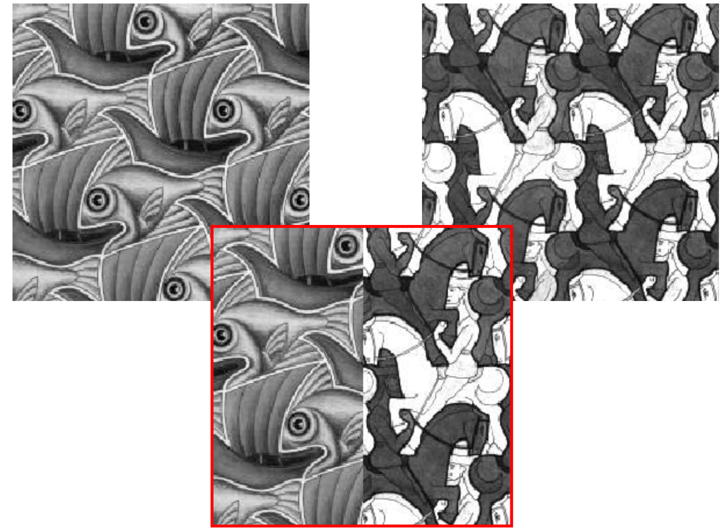
Same basic approach works for any transformation

- Translation, rotation, homographies, etc.
- Very useful tool

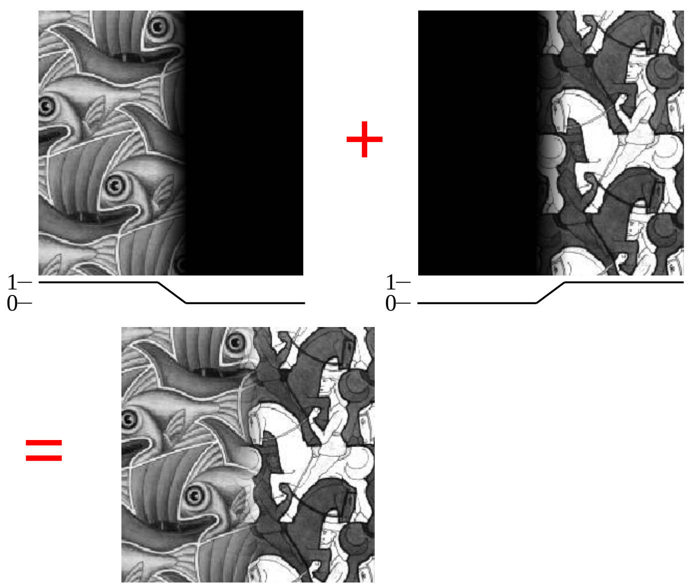
General version

- Randomly choose a set of K correspondences
  – Typically K is the minimum size that lets you fit a model
- Fit a model (e.g., homography) to those correspondences
- Count the number of inliers that “approximately” fit the model
  – Need a threshold on the error
- Repeat as many times as you can
- Choose the model that has the largest set of inliers
- Refine the model by doing a least squares fit using ALL of the inliers

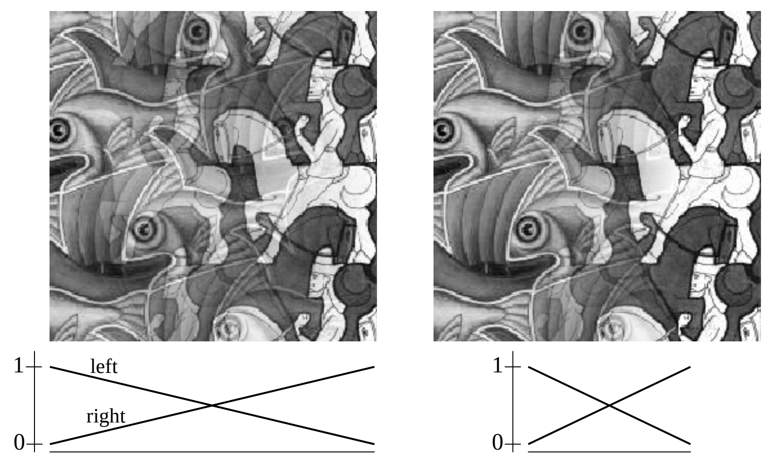
Image Blending



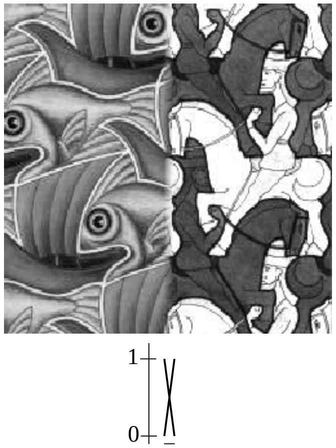
Feathering

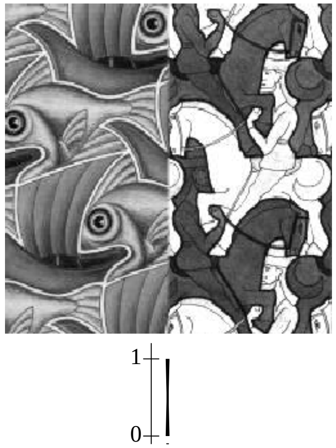


Effect of window size

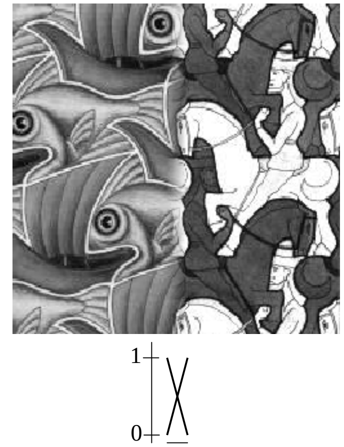


Effect of window size





Good window size

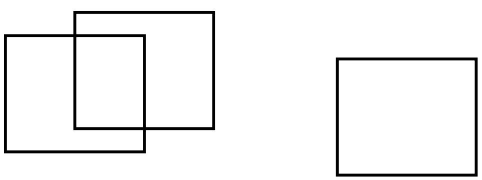


“Optimal” window: smooth but not ghosted

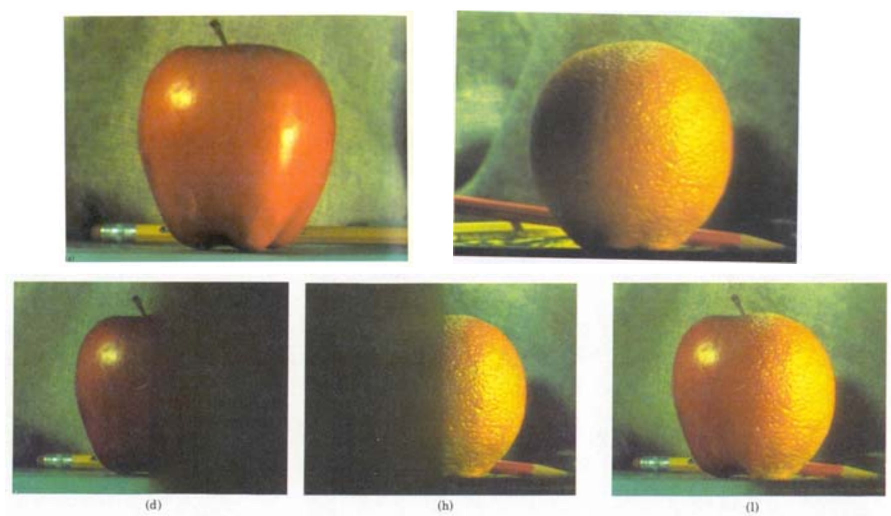
- Doesn’t always work...

Image feathering

What if you’re blending more than two images?



Pyramid blending



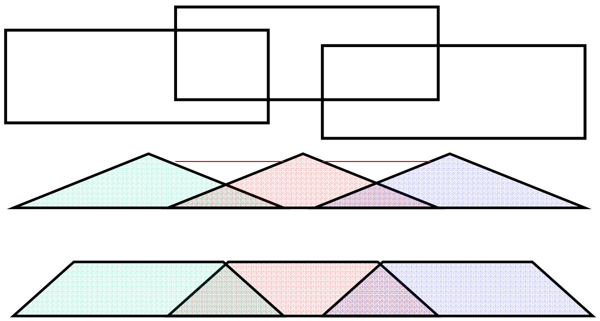
Create a Laplacian pyramid, blend each level

- Burt, P. J. and Adelson, E. H., A multiresolution spline with applications to image mosaics, ACM Transactions on Graphics, 42(4), October 1983, 217-236.

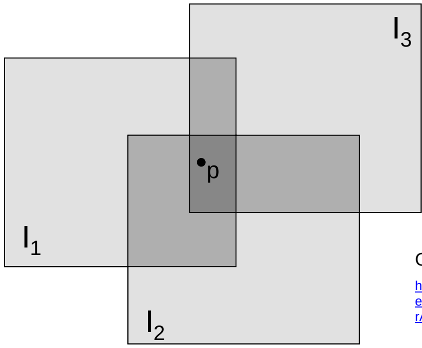
Image feathering

What if you have more than two images?

- Generate weight map for each image
  - typically want large weight at center, small weight at edge
- Each output pixel is a weighted average of inputs
  - be sure to divide by sum of weights at the end



Alpha Blending



Optional: see Blinn (CGA, 1994) for details: http://ieeexplore.ieee.org/iel1/38/7531/00310740.pdf?isNumber=7531&prod=JNL&arnumber=310740&arSt=83&ared=87&arAuthor=Blinn%2C+J.F.

Encoding blend weights: $I(x,y) = (\alpha R, \alpha G, \alpha B, \alpha)$

color at p = $\frac{(\alpha_1 R_1,\ \alpha_1 G_1,\ \alpha_1 B_1) + (\alpha_2 R_2,\ \alpha_2 G_2,\ \alpha_2 B_2) + (\alpha_3 R_3,\ \alpha_3 G_3,\ \alpha_3 B_3)}{\alpha_1 + \alpha_2 + \alpha_3}$

Implement this in two steps:

1. accumulate: add up the (α premultiplied) RGBα values at each pixel
2. normalize: divide each pixel's accumulated RGB by its α value

   Q: what if α = 0?

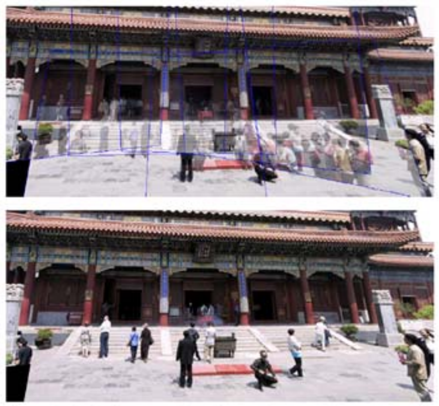
More advanced blending schemes

A quick survey...

Gradient-domain blending

Blend the gradients of the two images, then integrate
For more info: Perez et al, SIGGRAPH 2003
Also called "Poisson" blending

De-Ghosting



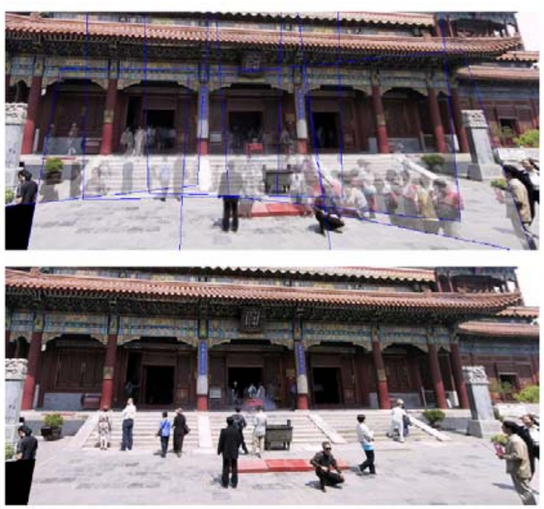
Local alignment (deghosting)

Use local optic flow to compensate for small motions
[Shum & Szeliski, ICCV'98]

Figure 3: Deghosting a mosaic with motion parallax: (a) with parallax; (b) after single deghosting step (patch size 32); (c) multiple steps (sizes 32, 16 and 8).

Photomontage [Agarwala et al., SIGGRAPH 2004]

- Each patch of the composite comes from a single image
- Solve for the seams that are hardest to detect (graph cuts)
- Blend across seams using gradient-domain blending



Photomontage [Agarwala et al., SIGGRAPH 2004]

Figure 1 From a set of five source images (of which four are shown on the left), we quickly create a composite family portrait in which everyone is smiling and looking at the camera (right). We simply flip through the stack and coarsely draw strokes using the *designated source* image objective over the people we wish to add to the composite. The user-applied strokes and computed regions are color-coded by the borders of the source images on the left (middle).

Photomontage [Agarwala et al., SIGGRAPH 2004]

Figure 6 We use a set of portraits (first row) to mix and match facial features, to either improve a portrait, or create entirely new people. The faces are first hand-aligned, for example, to place all the noses in the same location. In the first two images in the second row, we replace the closed eyes of a portrait with the open eyes of another. The user paints strokes with the *designated source* objective to specify desired features. Next, we create a fictional person by combining three source portraits. Gradient-domain fusion is used to smooth out skin tone differences. Finally, we show two additional mixed portraits.

Other types of mosaics

Can mosaic onto *any* surface if you know the geometry

- See NASA's [Visible Earth project](http://earthobservatory.nasa.gov/Newsroom/BlueMarble/) for some stunning earth mosaics
  - http://earthobservatory.nasa.gov/Newsroom/BlueMarble/

Slit images: cyclographs

Slit images: photofinish