Image Composition

COS 526
Princeton University

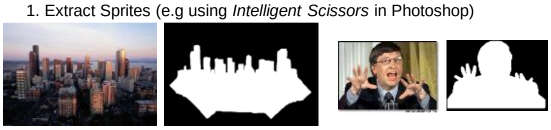
Modeled after lecture by Alexei Efros.
Slides by Efros, Durand, Freeman, Hays, Fergus, Lazebnik, Agarwala, Shamir, and Perez.

Image Composition

Jurassic Park

Image Blending

1. Extract Sprites (e.g using *Intelligent Scissors* in Photoshop)



2. Blend them into the composite (in the right order)

Composite by
David Dewey

Slide credit: A. Efros

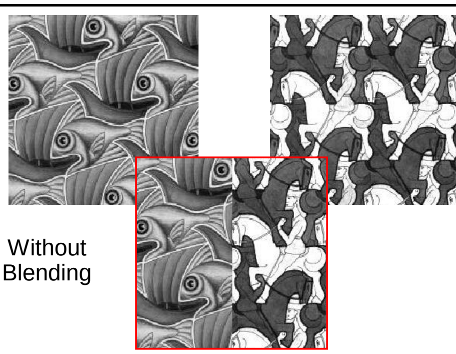
Image Composition

Laplacian pyramid blending
Graphcut seams
Poisson cloning

Image Composition

Laplacian pyramid blending ←
Graphcut seams
Poisson cloning

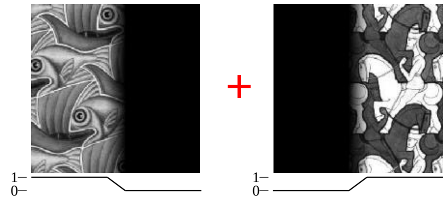
Image Blending



Without
Blending

Slide credit: A. Efros

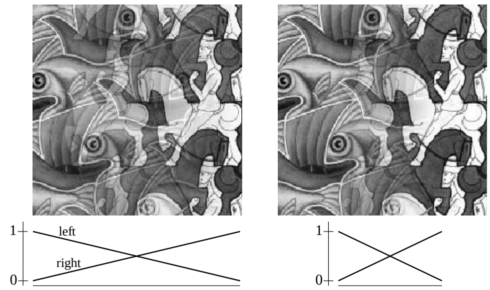
Alpha Blending / Feathering



$$I_{blend} = \alpha I_{left} + (1-\alpha) I_{right}$$

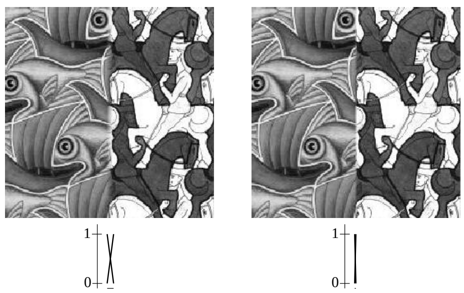
Slide credit: A. Efros

Affect of Window Size



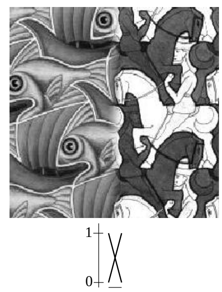
Slide credit: A. Efros

Affect of Window Size



Slide credit: A. Efros

Good Window Size



"Optimal" Window: smooth but not ghosted

Slide credit: A. Efros

What is the Optimal Window?

To avoid seams

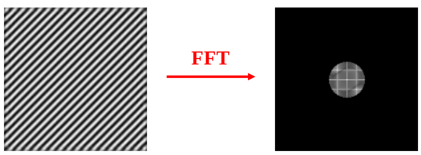
- window = size of largest prominent feature

To avoid ghosting

- window <= 2*size of smallest prominent feature

Natural to cast this in the *Fourier domain*

- largest frequency <= 2*size of smallest frequency
- image frequency content should occupy one "octave" (power of two)



Slide credit: A. Efros

What if the Frequency Spread is Wide

Idea (Burt and Adelson)

- Different window sizes for different frequencies

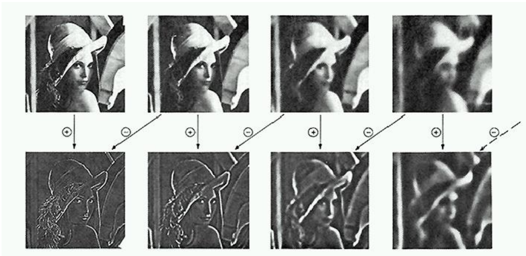
Method

- Decompose image into octaves (frequency bands)
- Feather each octave with appropriate window size
- Sum feathered octave images to reconstruct blended image

Slide credit: A. Efros

Laplacian Pyramid

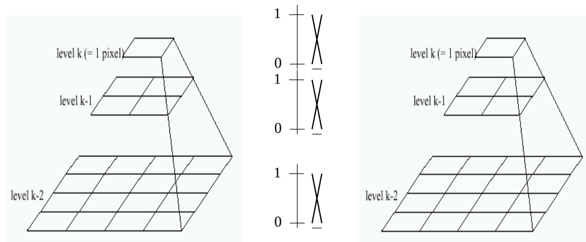
Lowpass Images



Bandpass Images

Slide credit: A. Efros

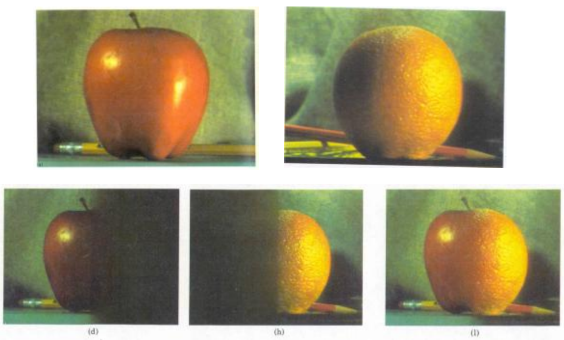
Laplacian Pyramid Blending



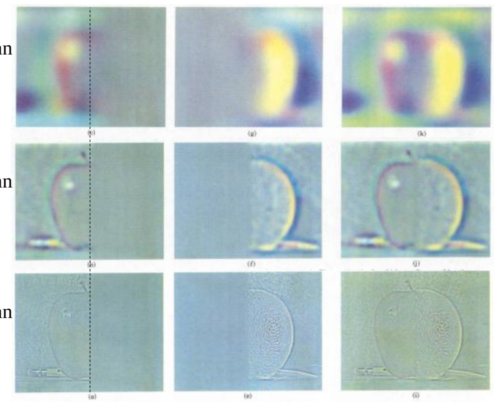
Left pyramid | blend | Right pyramid

Slide credit: A. Efros

Laplacian Pyramid Blending



Slide credit: A. Efros



laplacian level 4

laplacian level 2

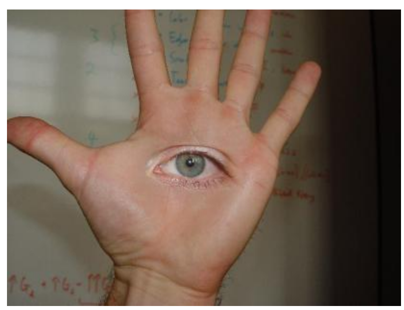
laplacian level 0

left pyramid | right pyramid | blended pyramid

Laplacian Pyramid Blending

Slide credit: A. Efros

Laplacian Pyramid Blending



© david dmartin (Boston College)

Slide credit: A. Efros

Problems with blending

Misaligned (moving) objects become ghosts

Slide credit: A. Efros

Image Composition

Laplacian pyramid blending
Graph cut seams ←
Poisson cloning

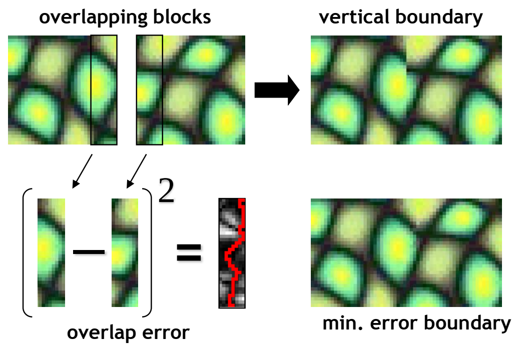
Graph Cuts

General idea

- Single source image per segment (avoids blurring)
- Careful cut placement, plus optional blending (avoids seams)

Slide credit: A. Efros

Graph Cuts in Texture Synthesis



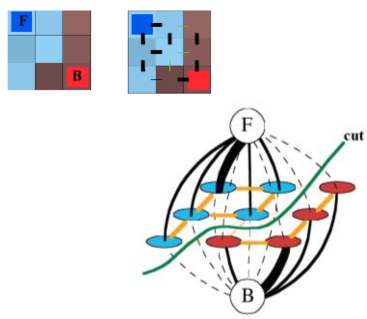
Slide credit: A. Efros

Graph Cuts in Image Segmentation

Lazy Snapping
Interactive segmentation using graphcuts

Graph Cut Algorithm

Boykov&Jolly, ICCV'01



Minimum cost cut can be computed in polynomial time
(max-flow/min-cut algorithms)

F	F	B
F	F	B
F	B	B

Graph cuts in Image Retargeting

Cropping

Seam Carving

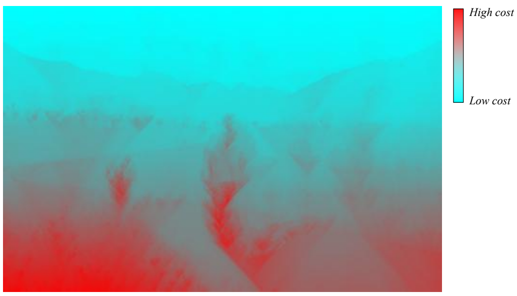
Scaling

Shamir

Seam Carving

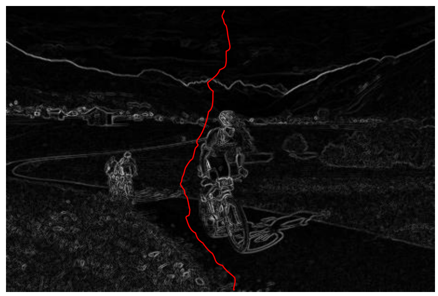
Shamir

Seam Carving



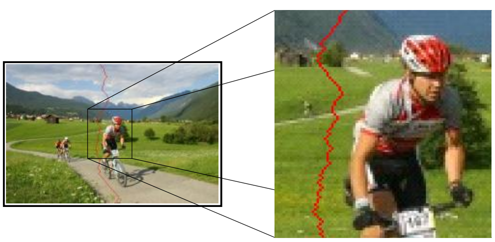
Shamir

Seam Carving



Shamir

Seam Carving



Shamir

Seam Carving

Shamir

Problem with graph cuts

What if colors/intensities are different?

Slide credit: F. Durand

Image Composition

Laplacian pyramid blending

Graphcut seams

Poisson cloning ←

Gradient domain image editing

Motivation:

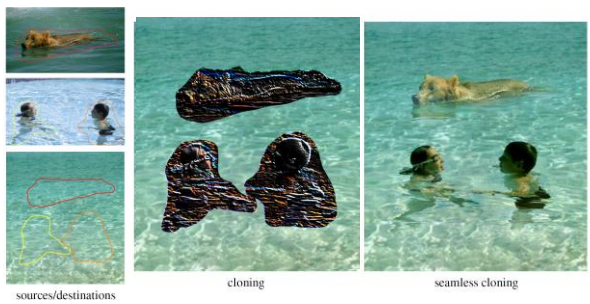
- Human visual system is very sensitive to gradient
- Gradient encode edges and local contrast quite well

Approach:

- Edit in the gradient domain
- Reconstruct image from gradient

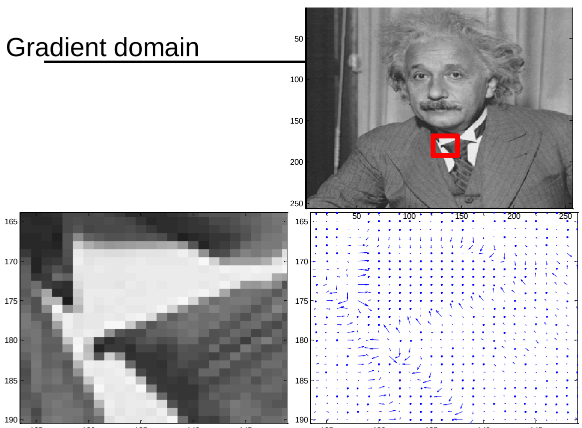
Slide credit: F. Durand

Gradient domain image editing



Slide credit: F. Durand

Gradient domain

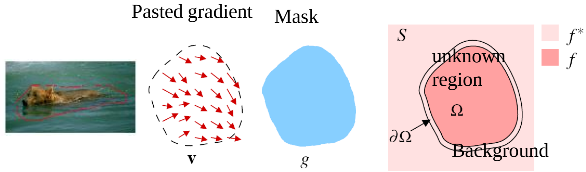


Slide credit: F. Durand

Seamless Poisson cloning

Given vector field *v* (pasted gradient), find the value of *f* in unknown region that optimizes:

$$\min_f \iint_\Omega |\nabla f - \mathbf{v}|^2 \text{ with } f|_{\partial\Omega} = f^*|_{\partial\Omega}$$



Slide credit: F. Durand

Discrete Poisson solver

Minimize variational problem $\min_f \iint_\Omega |\nabla f - \mathbf{v}|^2 \text{ with } f|_{\partial\Omega} = f^*|_{\partial\Omega}$

$$\min_{f|_\Omega} \sum_{\langle p,q\rangle \cap \Omega \neq \emptyset} (f_p - f_q - v_{pq})^2, \text{ with } f_p = f_p^*, \text{for all } p \in \partial\Omega$$

Discretized gradient

(all pairs that are in Ω)

Discretized v: g(p)-g(q)

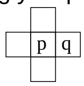
Boundary condition

Rearrange and call N_p the neighbors of p

$$\text{for all } p \in \Omega, \quad |N_p| f_p - \sum_{q \in N_p \cap \Omega} f_q = \sum_{q \in N_p \cap \partial\Omega} f_q^* + \sum_{q \in N_p} v_{pq}$$

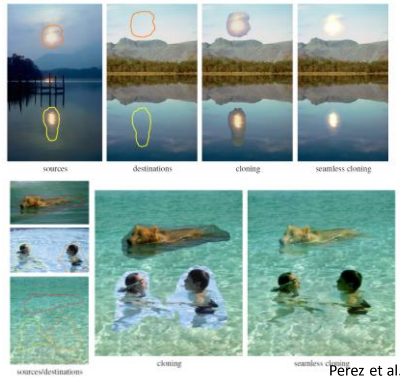
Only for boundary pixels

Big yet sparse linear system



Slide credit: F. Durand

Image Composition Results



Perez et al. SIGGRAPH 03

Perez et al. SIGGRAPH 03

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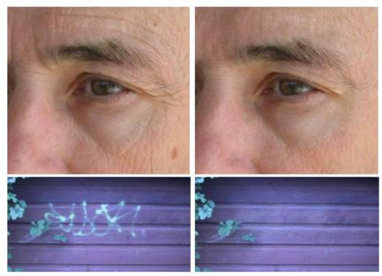

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Figure 2: **Concealment**. By importing seamlessly a piece of the background, complete objects, parts of objects, and undesirable artifacts can easily be hidden. In both examples, multiple strokes (not shown) were used.

Perez et al. SIGGRAPH 03

Putting it all together

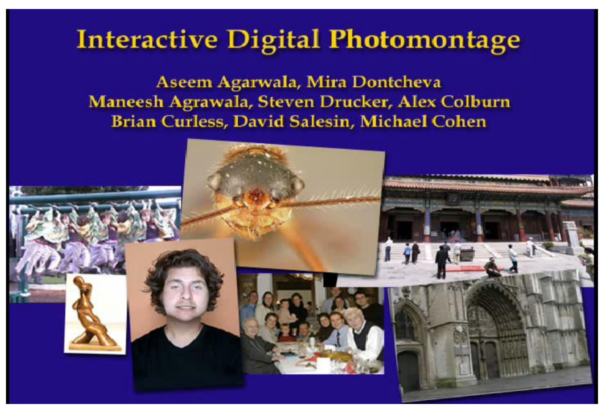
Compositing images

- Have a clever blending function
  - Feathering
  - Laplacian pyramid
  - Poisson cloning
- Choose the right pixels from each image
  - Graphcuts

Now, let's put it all together:

- Photomontage [Agarwala et al. 2004]
- Scene Completion [Hayes et al. 2007]

Slide credit: A. Efros



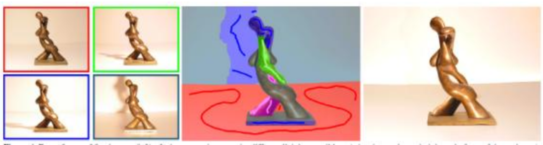
Interactive Digital Photomontage

Agarwala et al. SIGGRAPH 04

Interactive Digital Photomontage

Agarwala et al. SIGGRAPH 04

Interactive Digital Photomontage

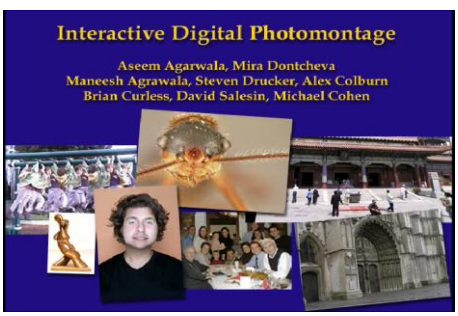


Agarwala et al. SIGGRAPH 04

Interactive Digital Photomontage

Agarwala et al. SIGGRAPH 04

Interactive Digital Photomontage



Scene Completion Using Millions of Photographs

James Hays and Alexei A. Efros
SIGGRAPH 2007

Slides by J. Hays and A. Efros

Hays et al. SIGGRAPH 07

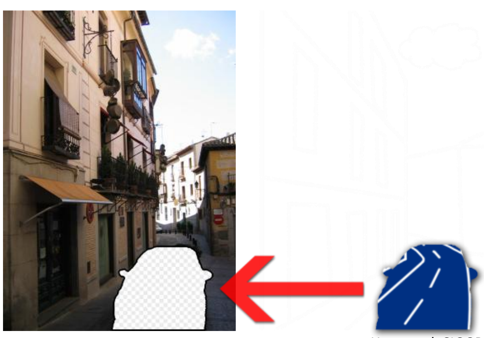
Hays et al. SIGGRAPH 07

Efros and Leung result

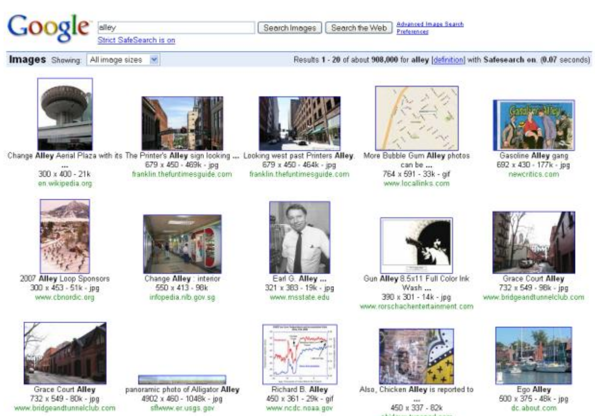
Hays et al. SIGGRAPH 07

Hays et al. SIGGRAPH 07

Scene Matching for Image Completion



Hays et al. SIGGRAPH 07



Hays et al. SIGGRAPH 07

Data

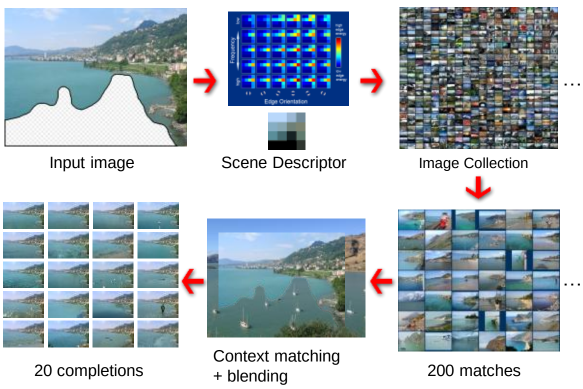
2.3 Million unique images from Flickr groups and keyword searches.

Hays et al. SIGGRAPH 07

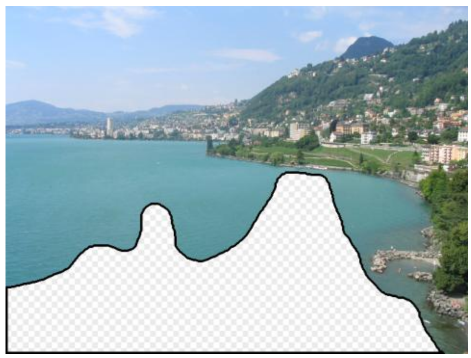
Scene Completion Result

Hays et al. SIGGRAPH 07

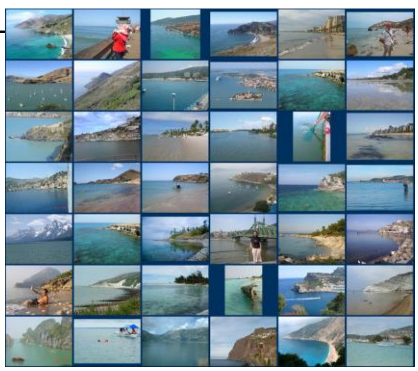
The Algorithm



Scene Matching



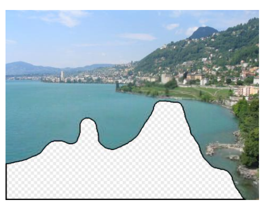
Hays et al. SIGGRAPH 07



… 200 total

Hays et al. SIGGRAPH 07

Context Matching



Hays et al. SIGGRAPH 07

Hays et al. SIGGRAPH 07

Summary

Compositing images

- Have a clever blending function
  - Feathering
  - Laplacian pyramid
  - Poisson cloning
- Choose the right pixels from each image
  - Graphcuts

Applications:

- Interactive Digital Photomontage
- Scene completion from millions of images

Slide credit: A. Efros