Image Composition

COS 526: Advanced Computer Graphics

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)

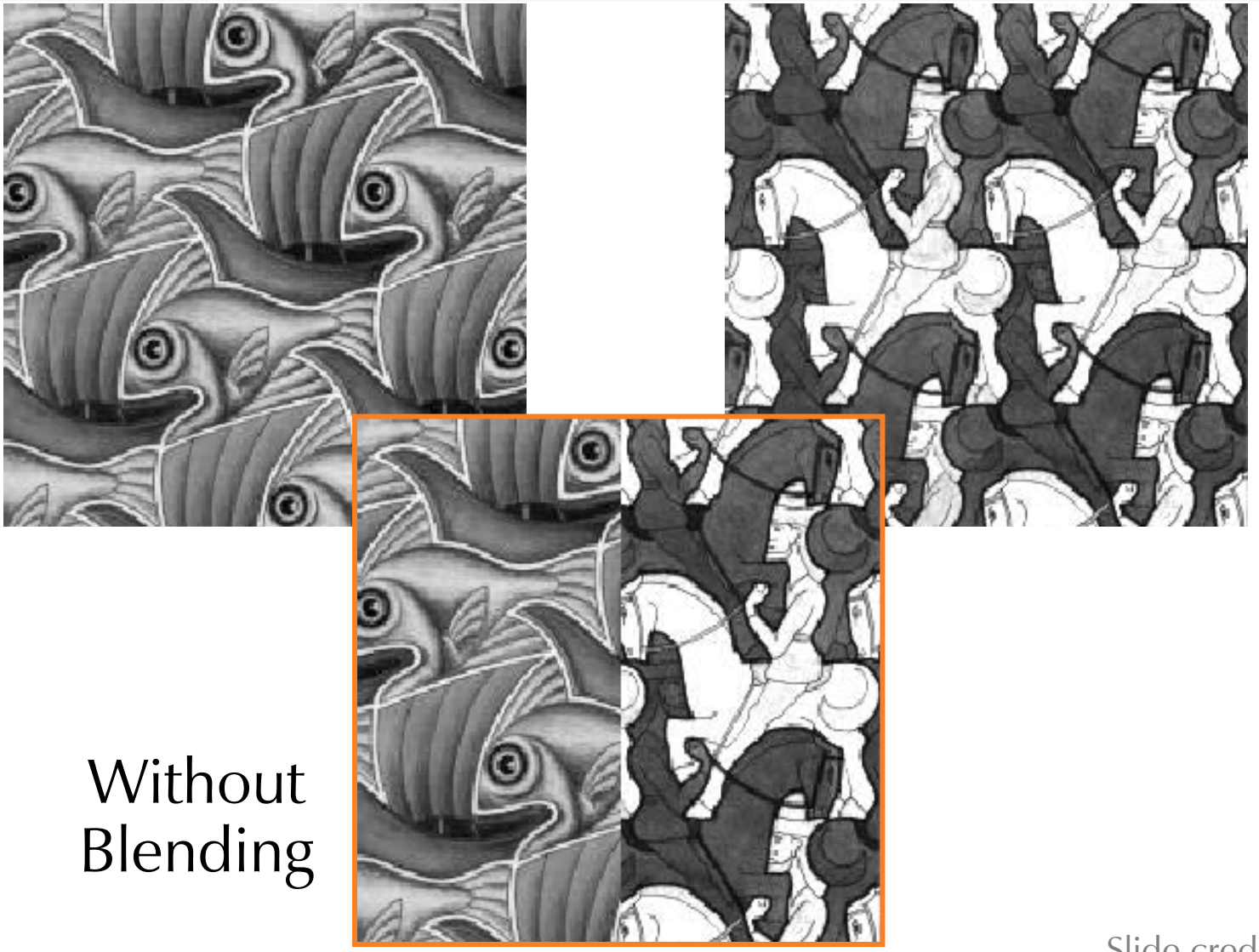
Composite by
David Dewey

Slide credit: A. Efros

Image Composition

- Laplacian pyramid blending
- Graphcut seams
- Poisson cloning

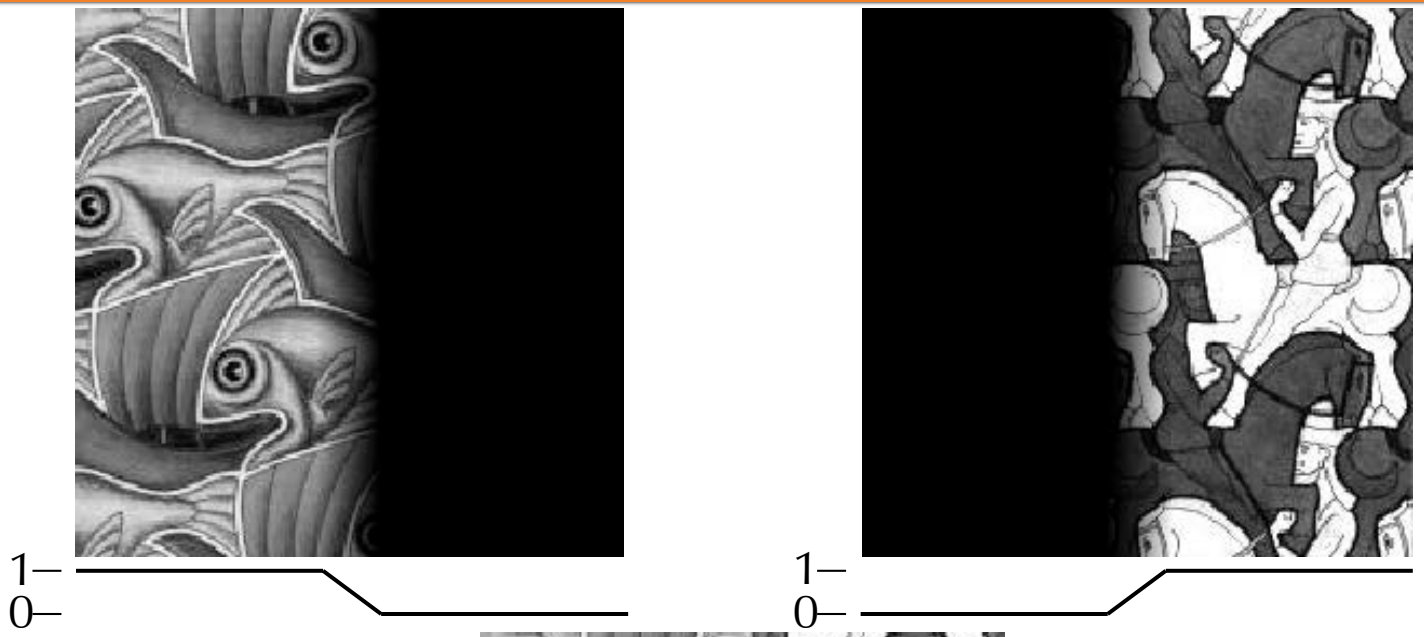
Image Blending



Without Blending

Slide credit: A. Efros

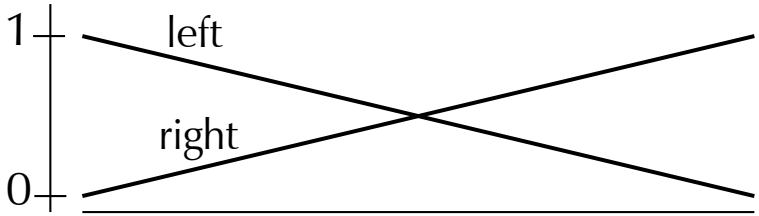
Alpha Blending / Feathering

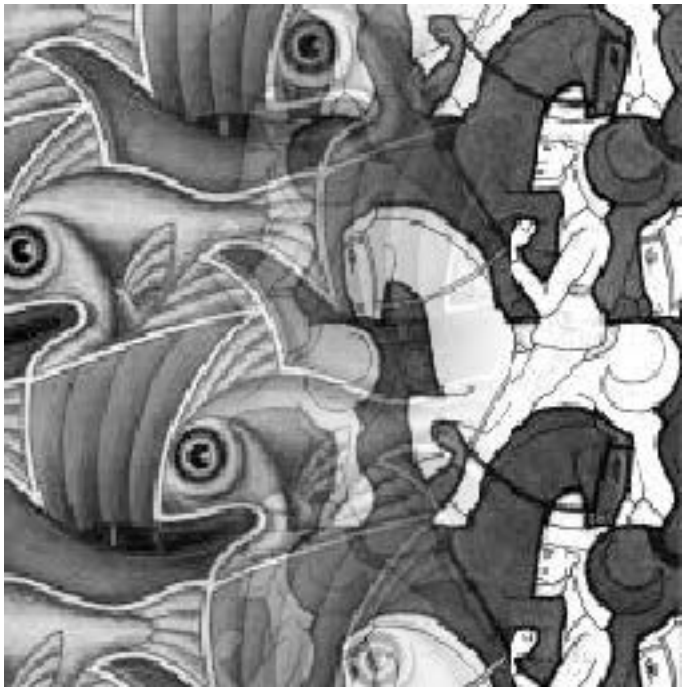


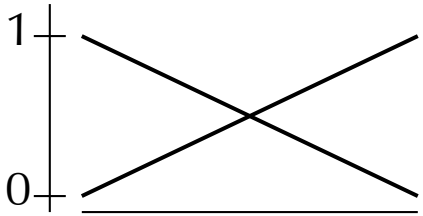
$$I_{blend} = \alpha I_{left} + (1-\alpha) I_{right}$$

Slide credit: A. Efros

Effect of Window Size

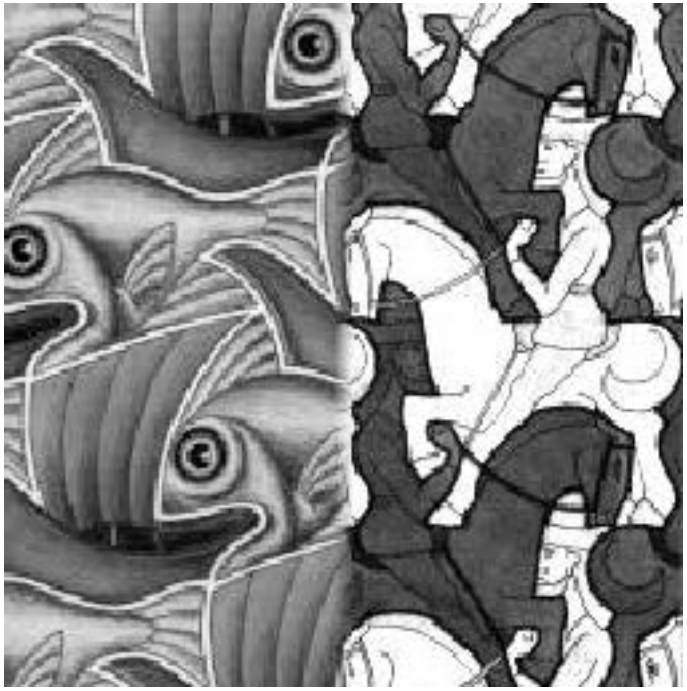


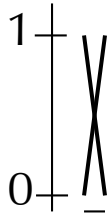


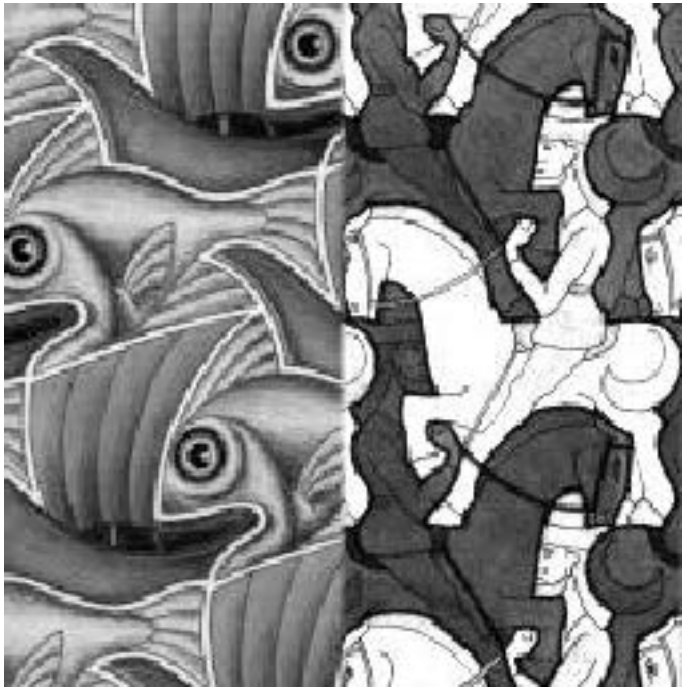


Slide credit: A. Efros

Effect of Window Size







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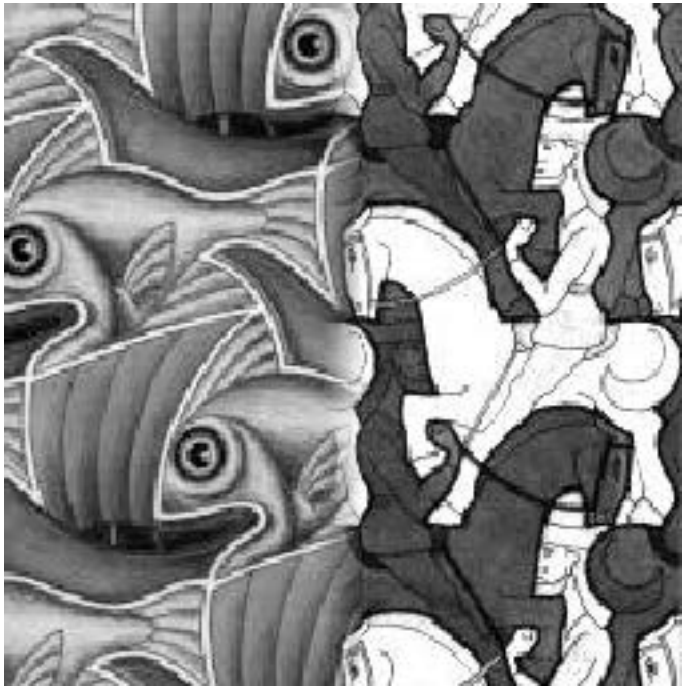
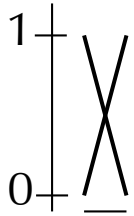
“Optimal” Window: Smooth, Not Ghosted





Slide credit: A. Efros

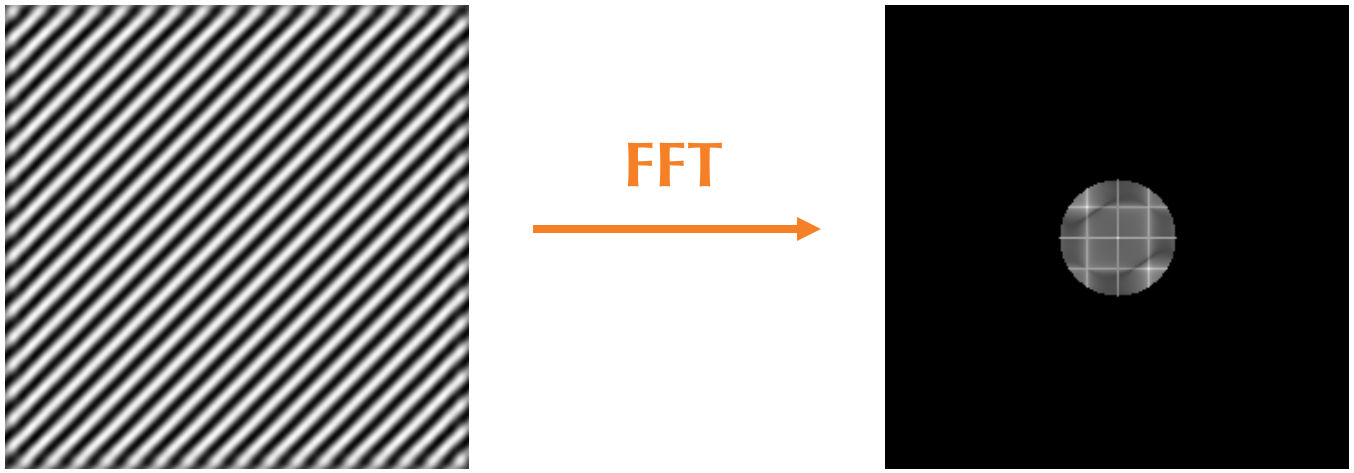
What is the Optimal Window?

- To avoid seams
  - window = size of largest prominent feature
- To avoid ghosting
  - window <= 2*size of smallest prominent feature

Slide credit: A. Efros

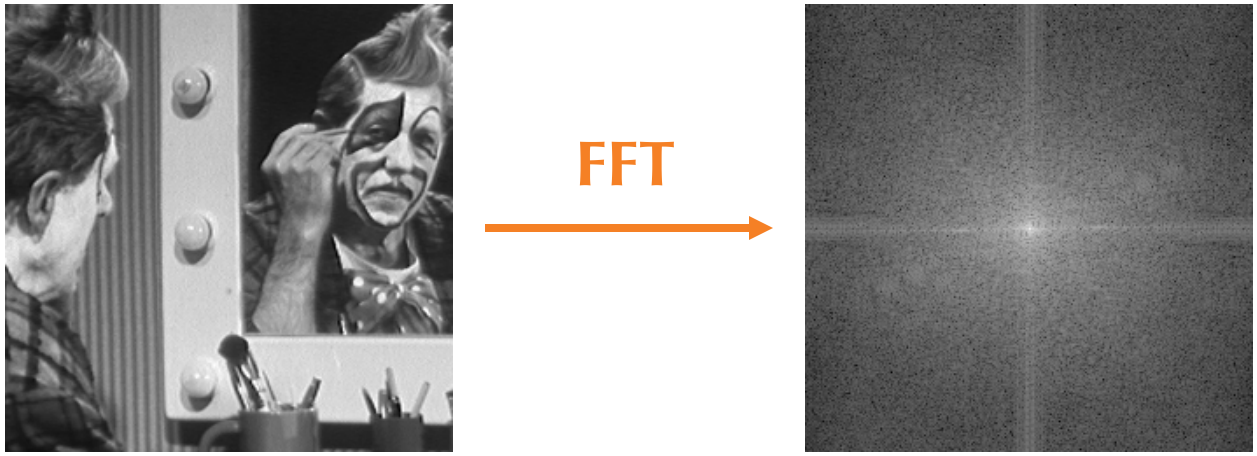
What is the Optimal Window?

- 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

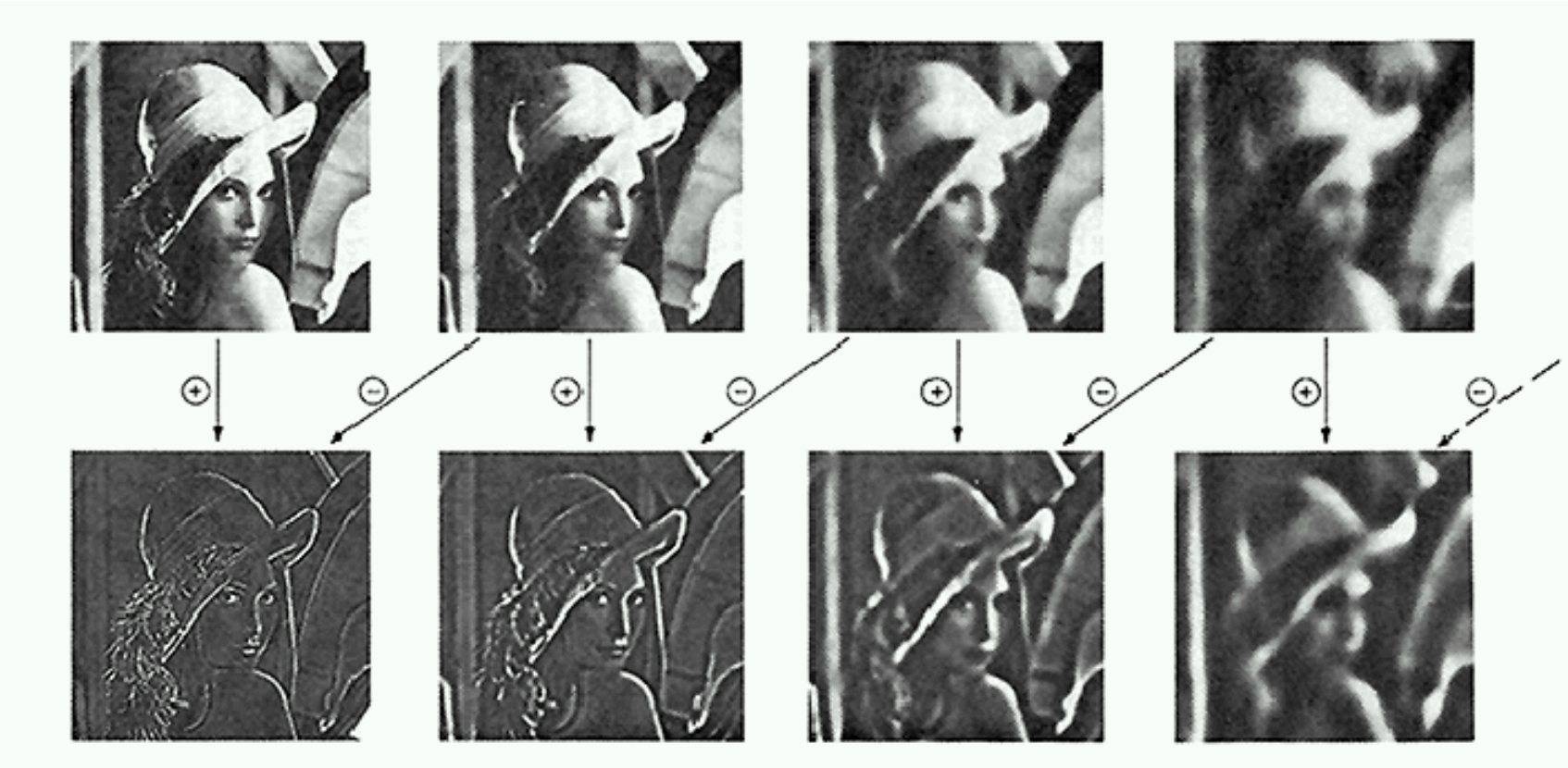


- Idea (Burt and Adelson)
  - Different window sizes for different frequencies
- Method
  - Decompose image into octaves (frequency bands)
  - Feather each octave with appropriate window size
  - Sum feathered octave images to reconstruct blended image

Slide credit: A. Efros

Laplacian Pyramid

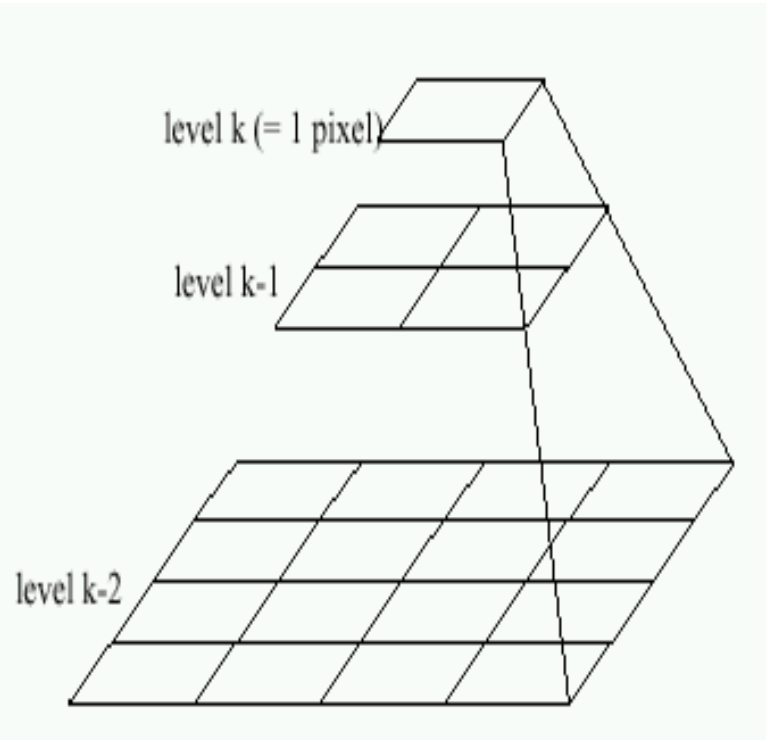
Lowpass Images

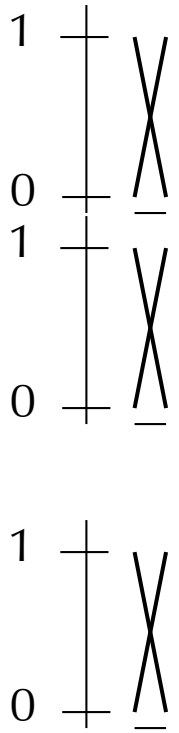


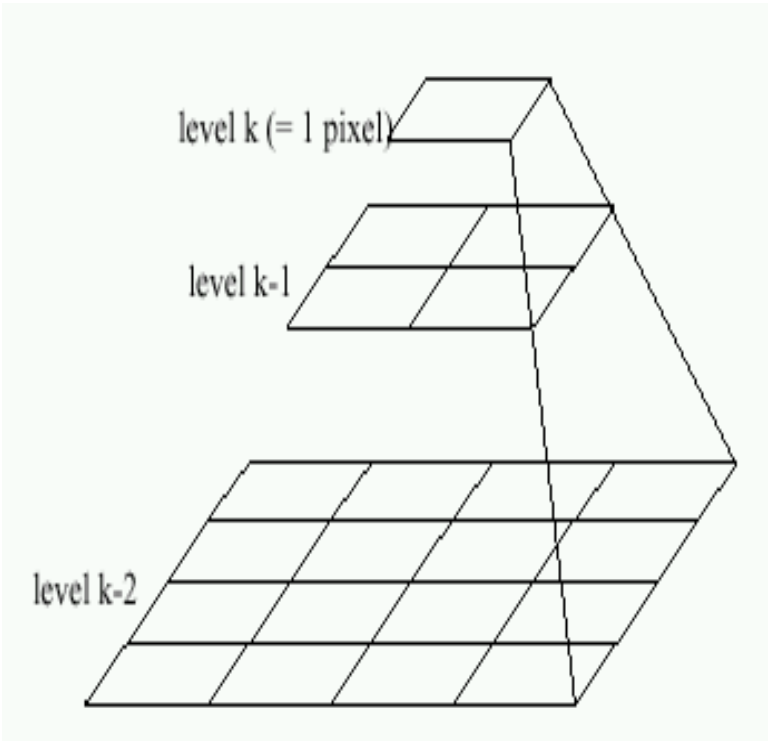
Bandpass Images

Slide credit: A. Efros

Laplacian Pyramid Blending







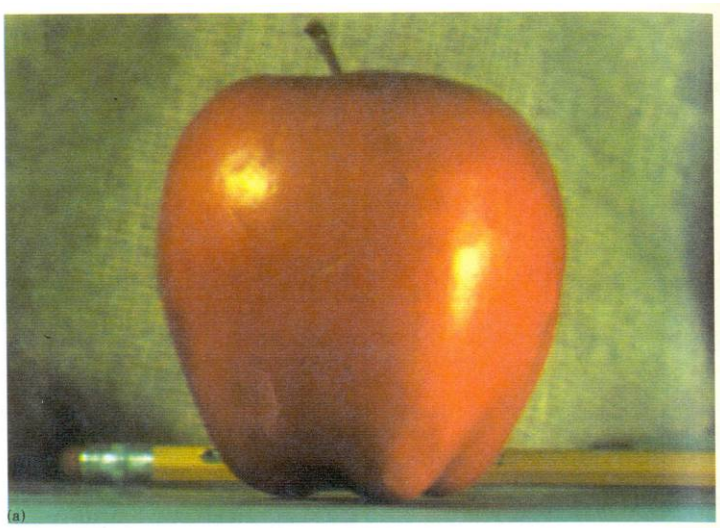
Left pyramid

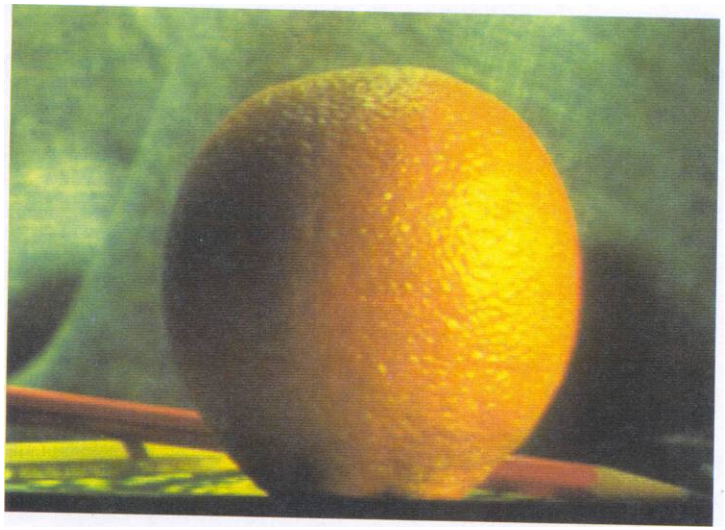
blend

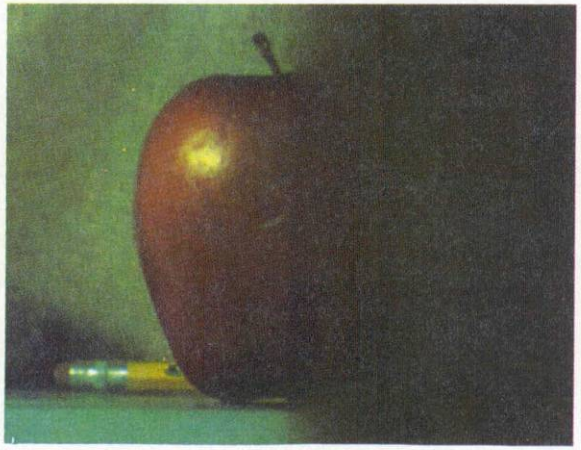
Right pyramid

Slide credit: A. Efros

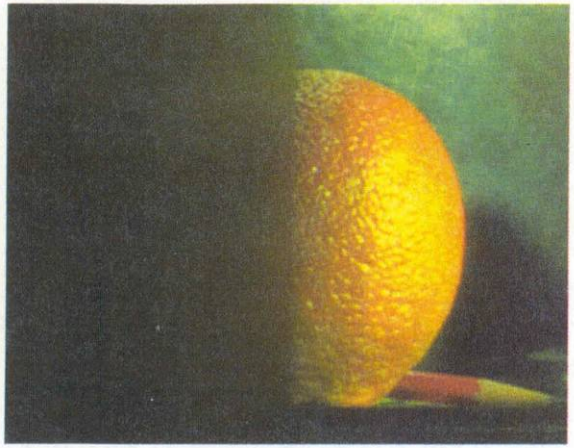
Laplacian Pyramid Blending



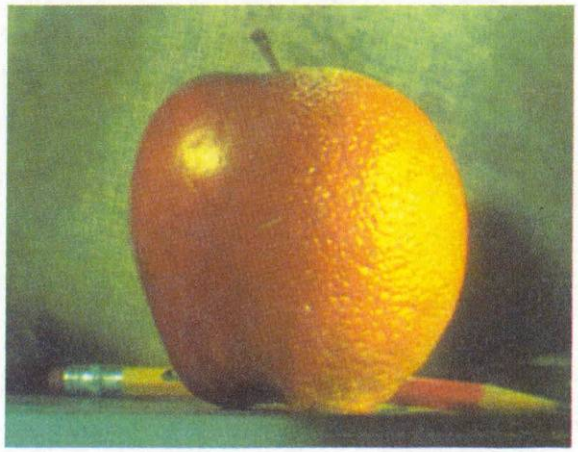




(d)



(h)



(l)

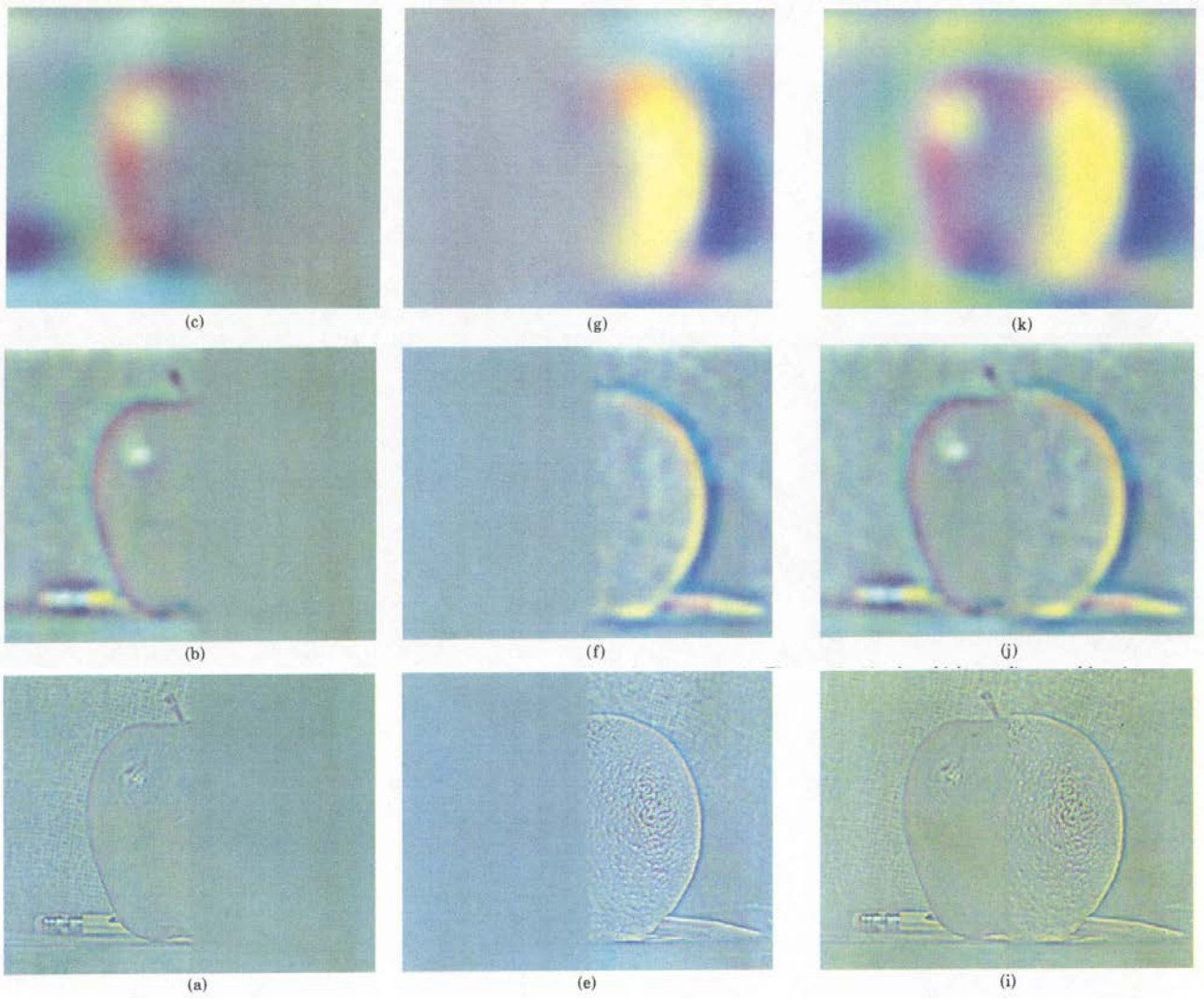
Slide credit: A. Efros

Laplacian Pyramid Blending

pyramid level 4

pyramid level 2

pyramid level 0

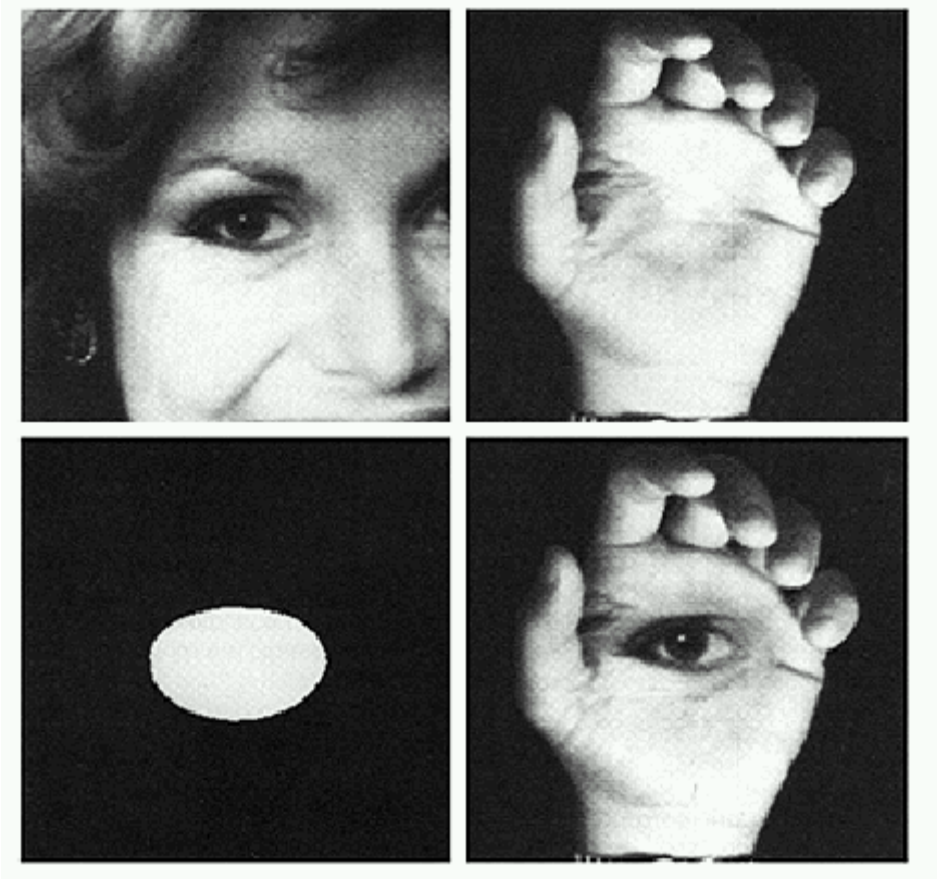


left pyramid

right pyramid

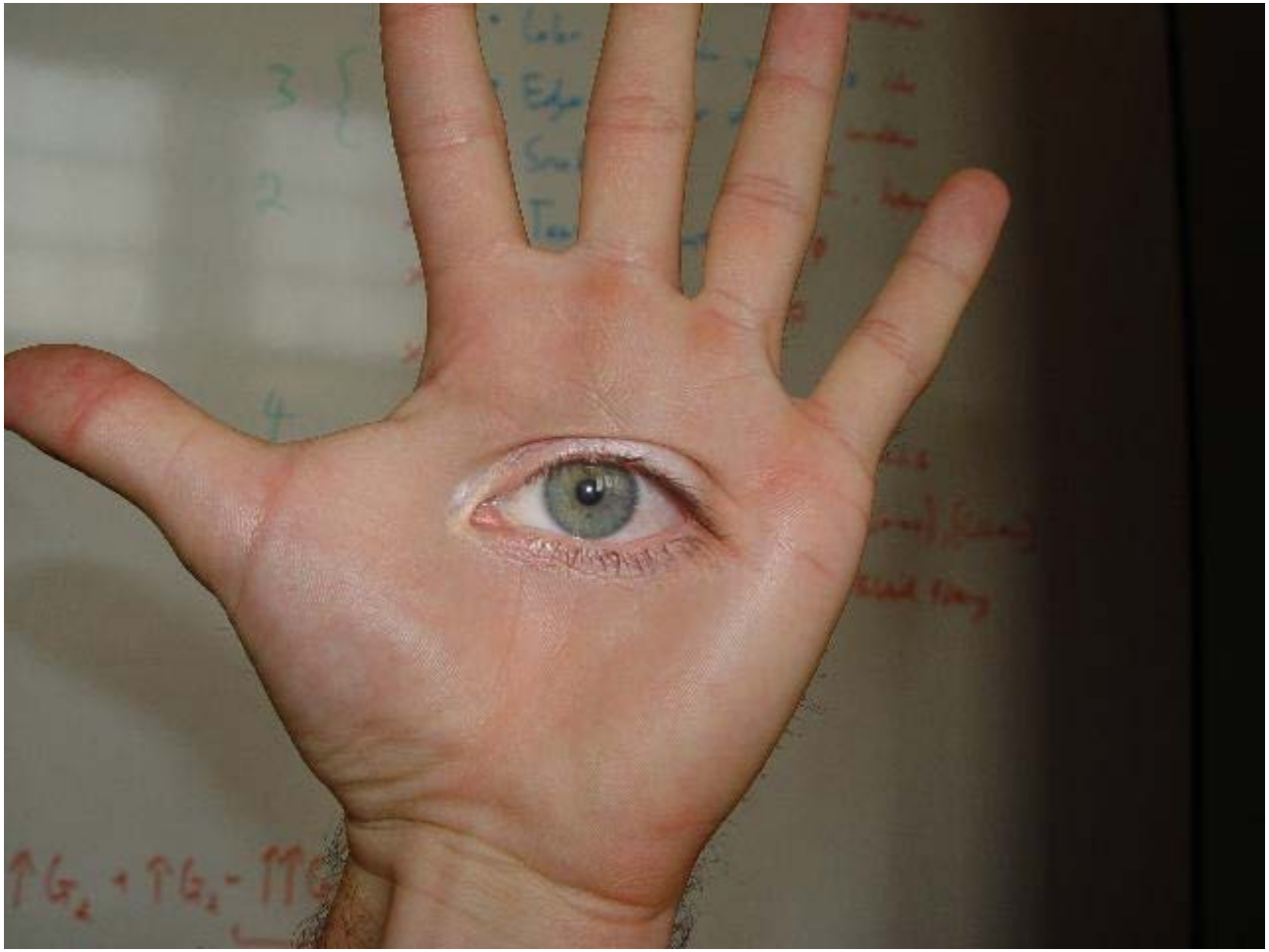
blended pyramid

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, optional blending (avoids seams)

Slide credit: A. Efros

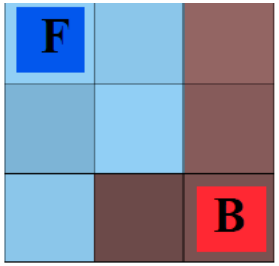
Graph Cuts in Image Segmentation

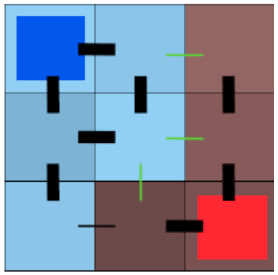
(a) Girl (4/2/12) (b) Ballet (4/7/14) (c) Boy (6/2/13)

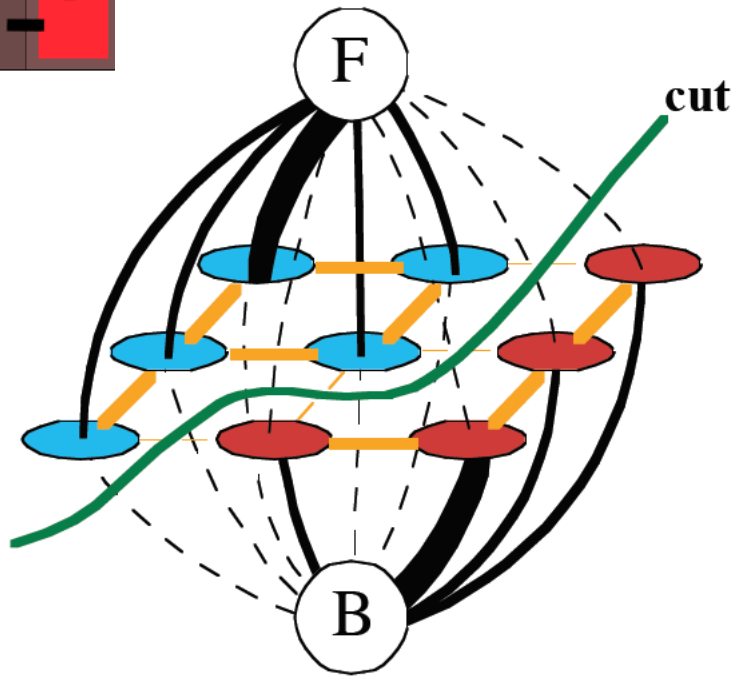
(c) Grandpa (4/2/11) (d) Twins (4/4/12)

Lazy Snapping
Interactive segmentation using graphcuts

Graph Cut Algorithm







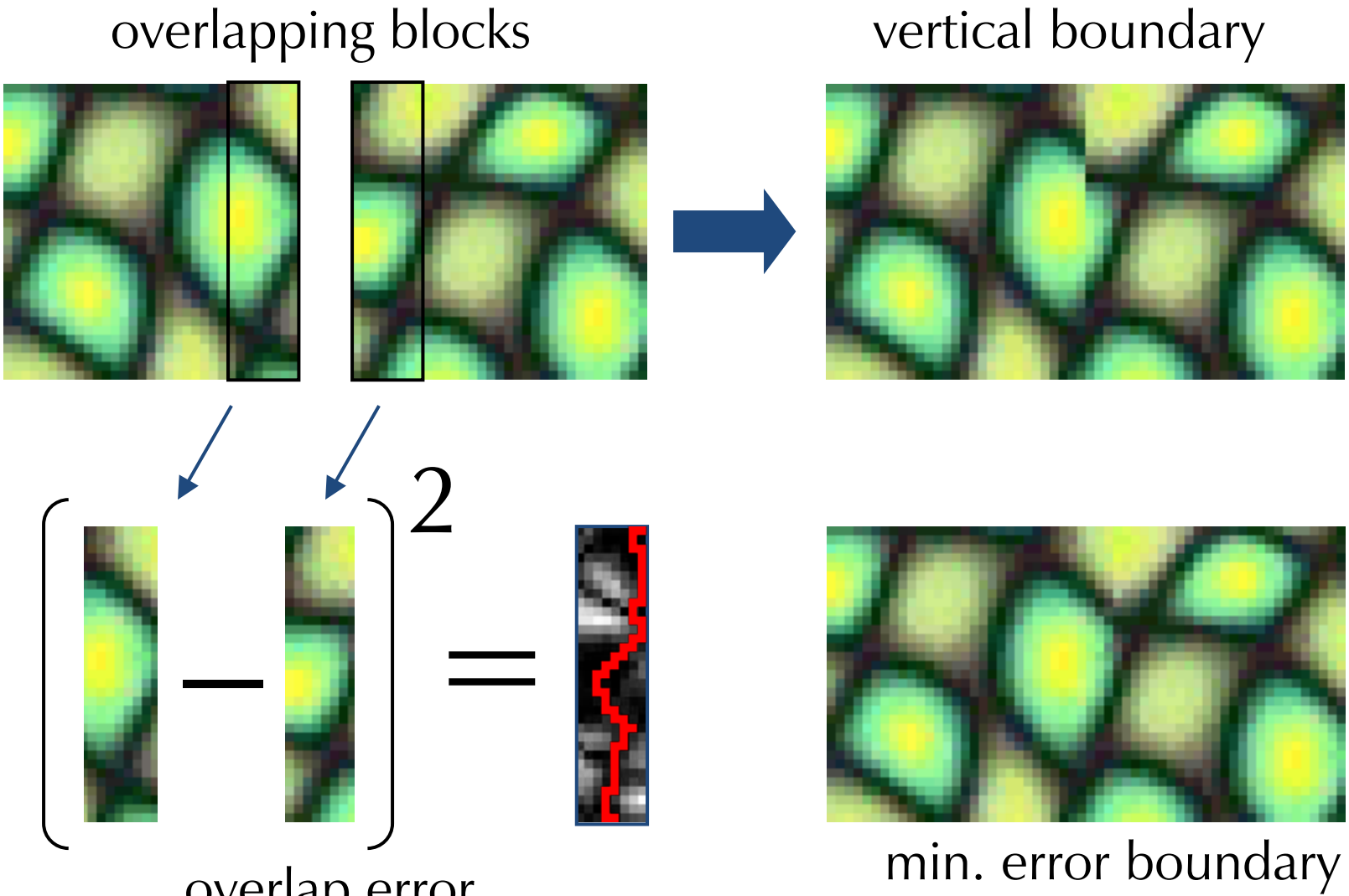
F	F	B
F	F	B
F	B	B

Minimum cost cut can be computed in polynomial time

(max-flow/min-cut algorithms)

Boykov & Jolly, ICCV'01

Graph Cuts in Texture Synthesis



Slide credit: A. Efros

Graph Cuts in Image Retargeting

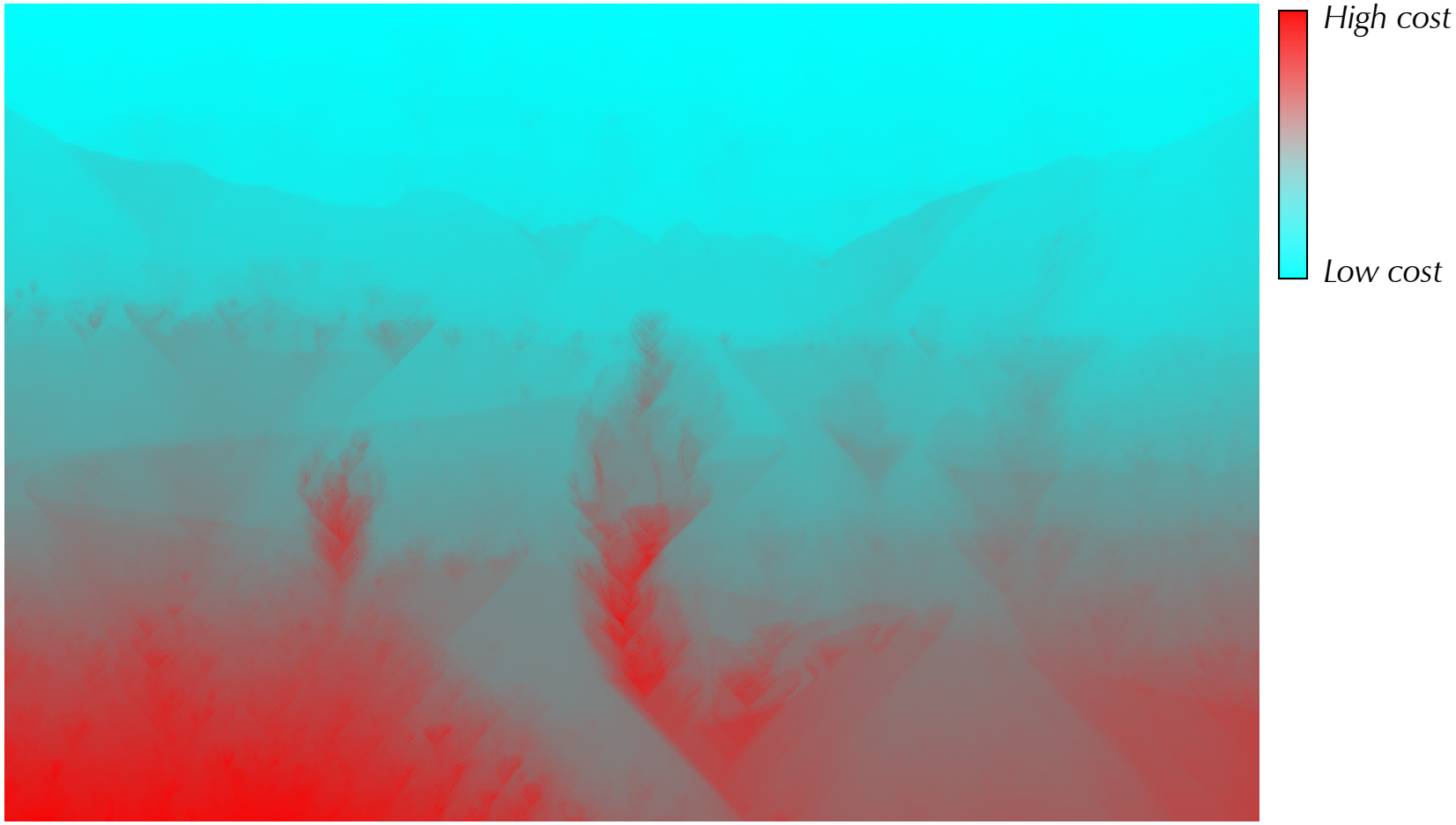
Cropping

Seam Carving

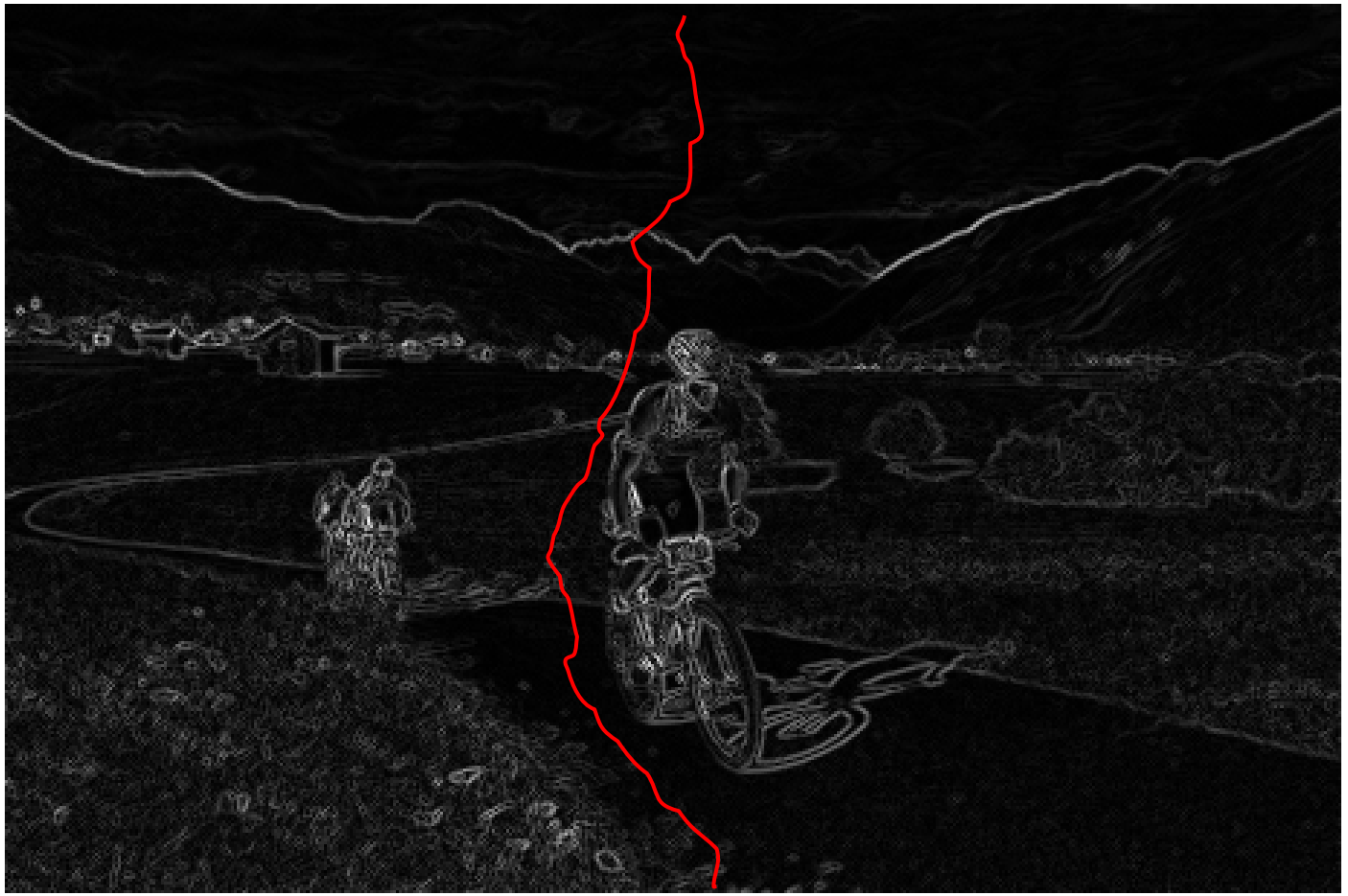
Scaling

Seam Carving

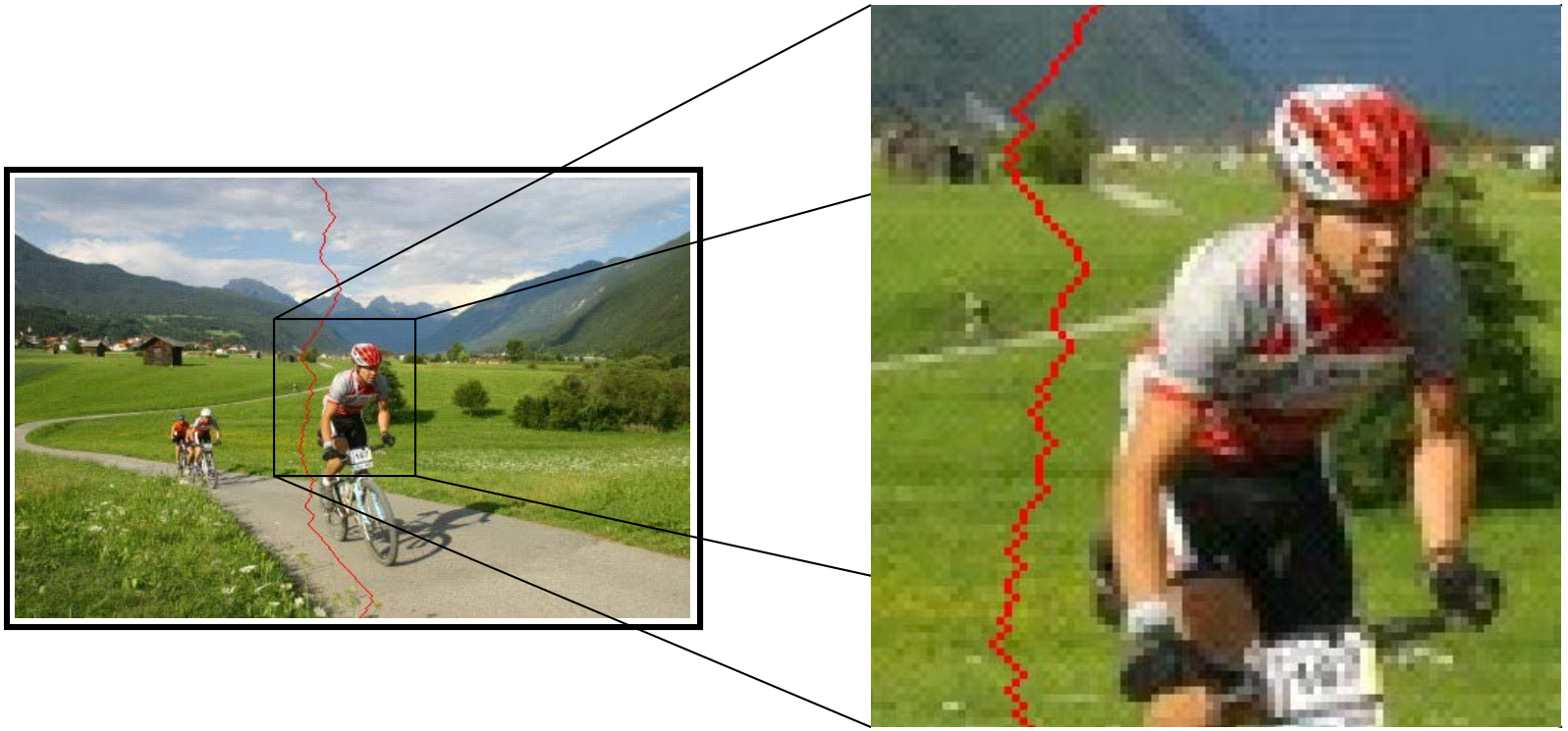
Seam Carving



Seam Carving



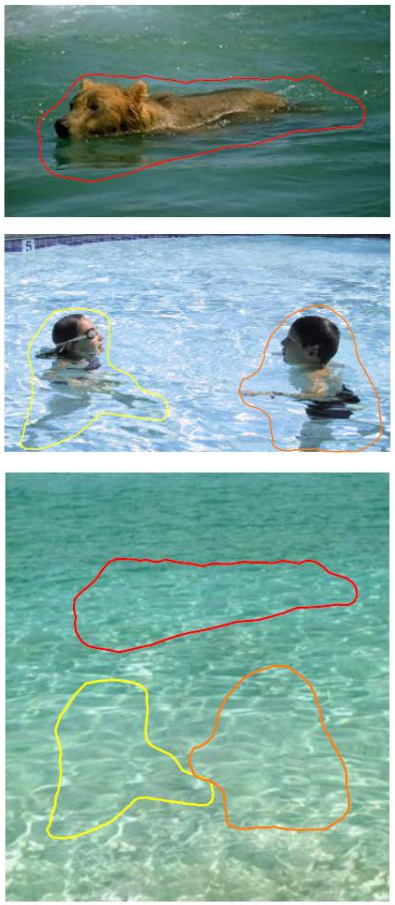
Seam Carving



Seam Carving

Problem with Graph Cuts

- What if colors/intensities are different?



sources/destinations

cloning

Slide credit: F. Durand

Image Composition

- Laplacian pyramid blending
- Graphcut seams
- Poisson cloning

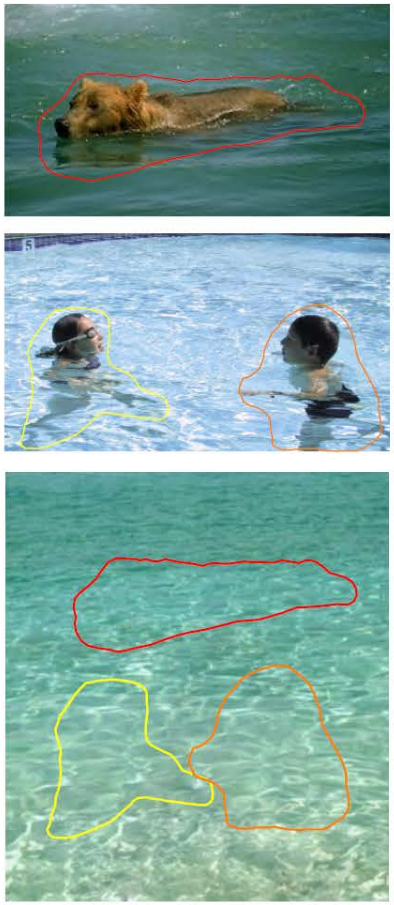
Gradient Domain Image Editing

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

- Approach:
  - Compute gradient(s) of source image(s)
  - Edit in the gradient domain
  - Reconstruct image from gradient

Slide credit: F. Durand

Gradient Domain Image Editing



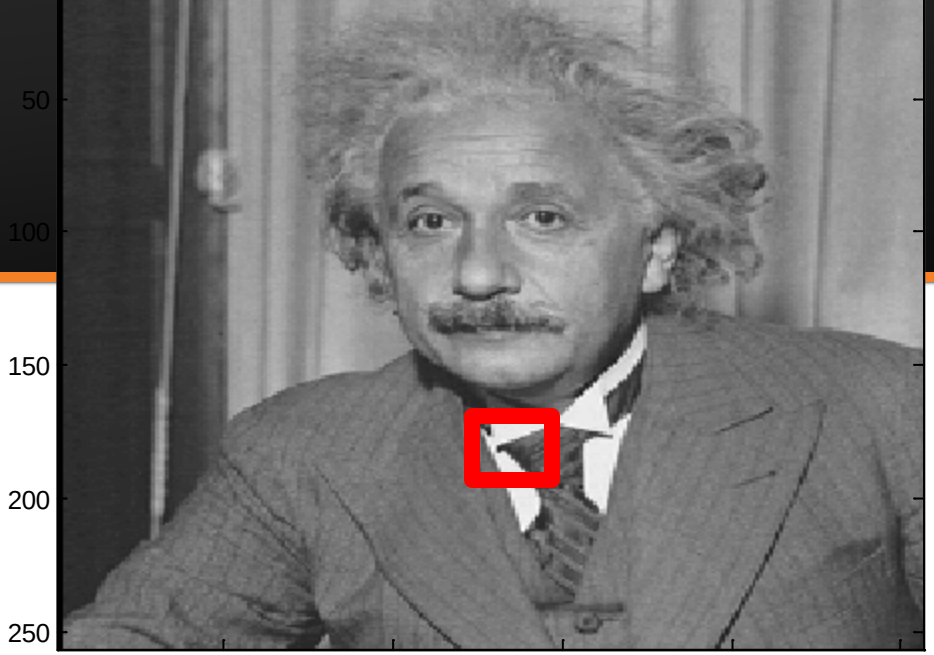
sources/destinations

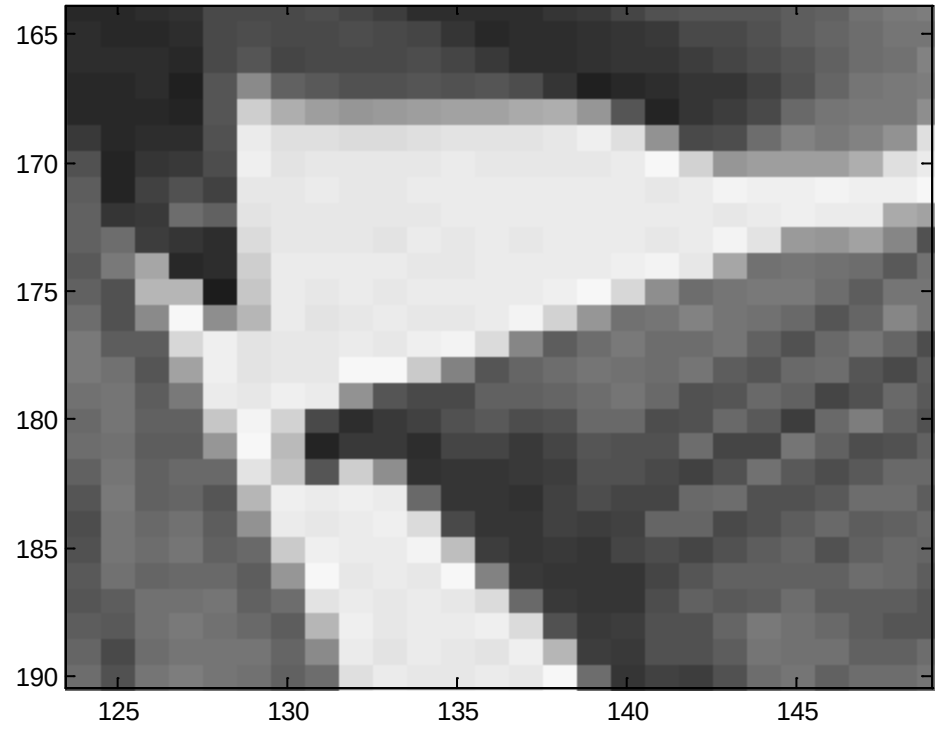
cloning

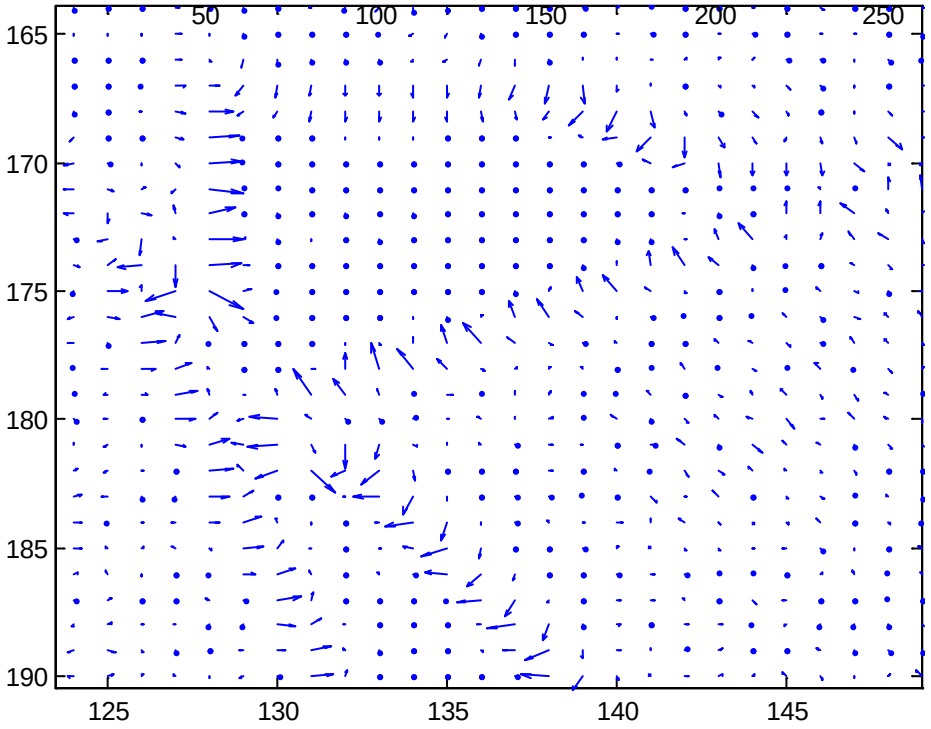
seamless cloning

Slide credit: F. Durand

Image Gradient





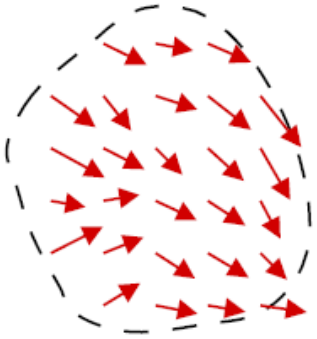


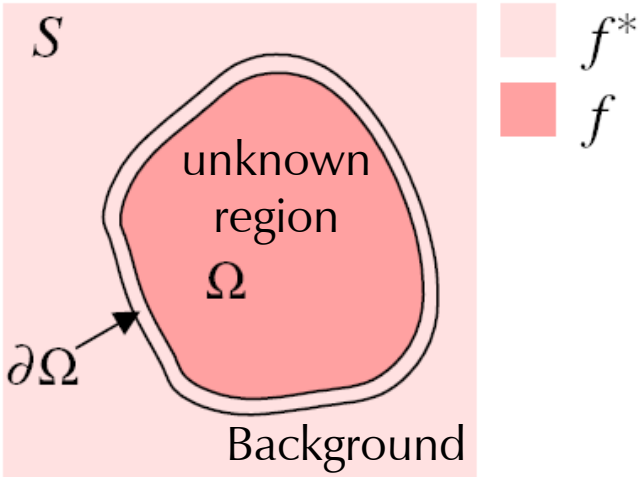
Slide credit: F. Durand

Poisson Cloning

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

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





Pasted gradient Mask

Slide credit: F. Durand

Discrete Poisson Solver

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

- Solving this problem in the continuous domain requires solving the Poisson differential equation
- But instead, we discretize and solve by least squares

Discretized gradient

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

(all pairs that are in Ω)

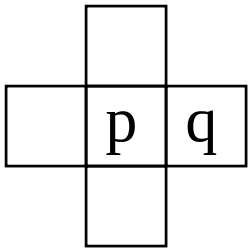
Discretized v: g(p)-g(q)

Boundary condition

Slide credit: F. Durand

Discrete Poisson Solver

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



- Rearrange and call N_p the neighbors of p

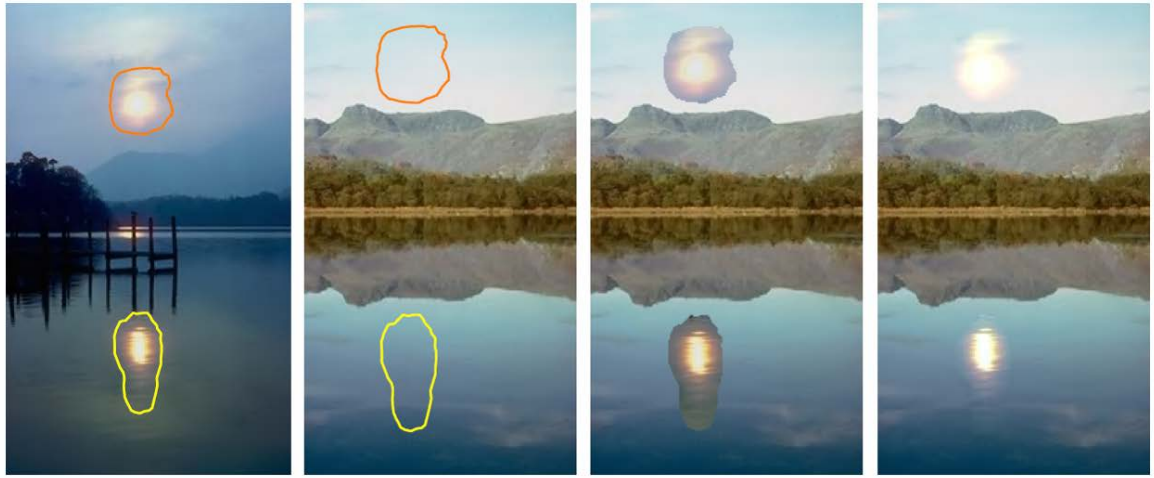
$$\text{for all } p \in \Omega, \quad |N_p| f_p - \sum_{q \in N_p \cap \Omega} f_q = \sum_{q \in N_p \cap \partial\Omega} f_q^* + \sum_{q \in N_p} v_{pq}$$

Only for boundary pixels

- Big yet sparse linear system

Slide credit: F. Durand

Image Composition Results

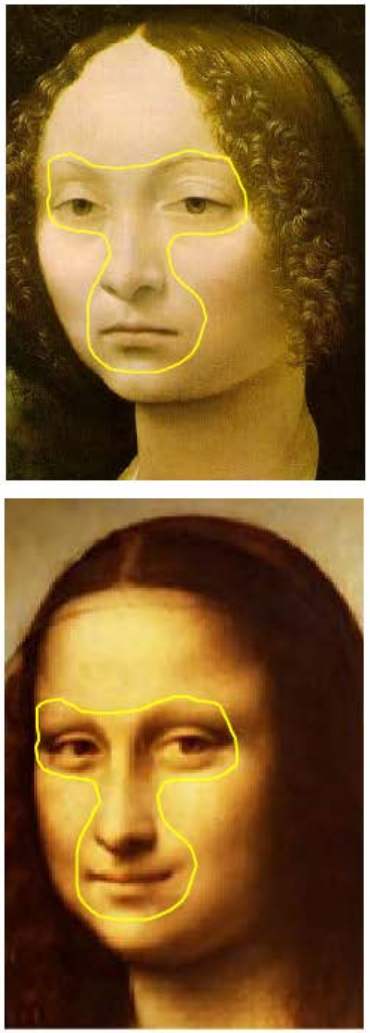


sources destinations cloning seamless cloning

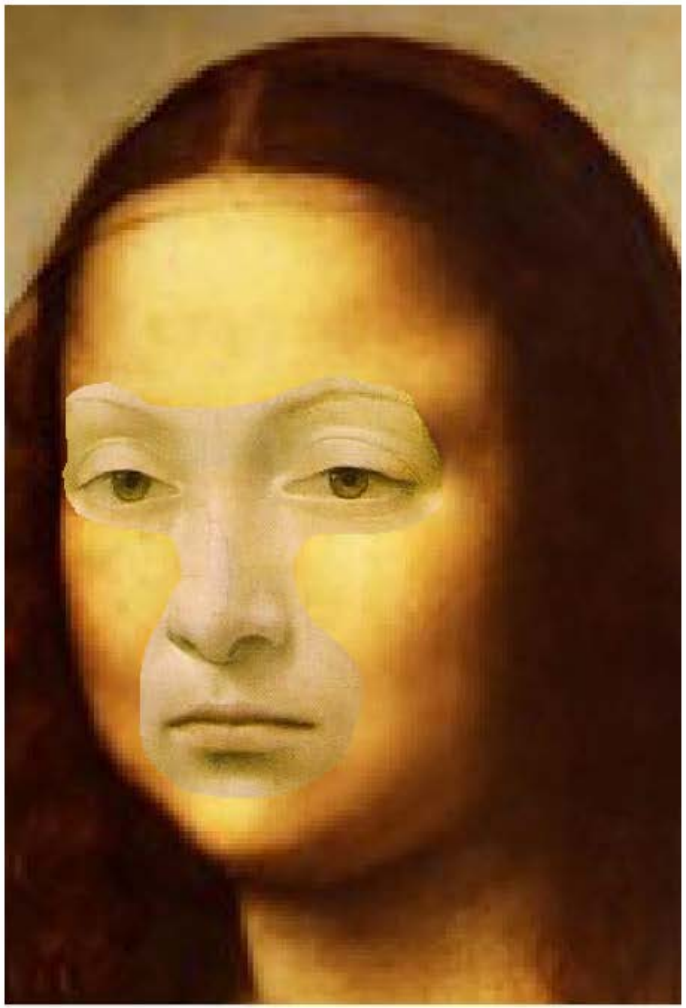
sources/destinations cloning seamless cloning

Perez et al. SIGGRAPH 03

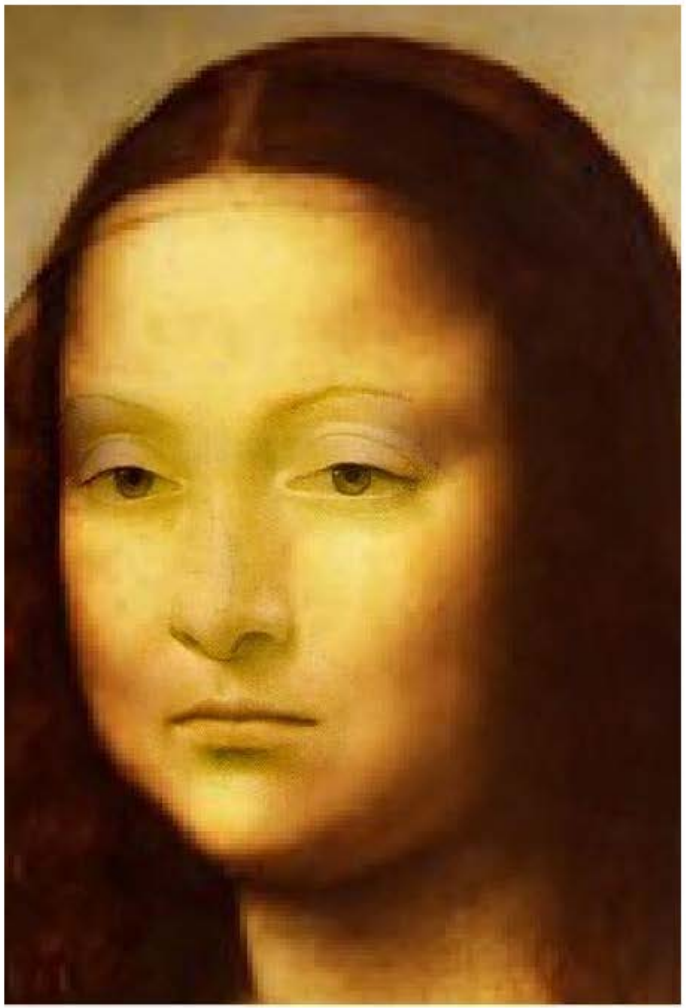
Image Composition Results



source/destination



cloning



seamless cloning

Perez et al. SIGGRAPH 03

Image Composition Results

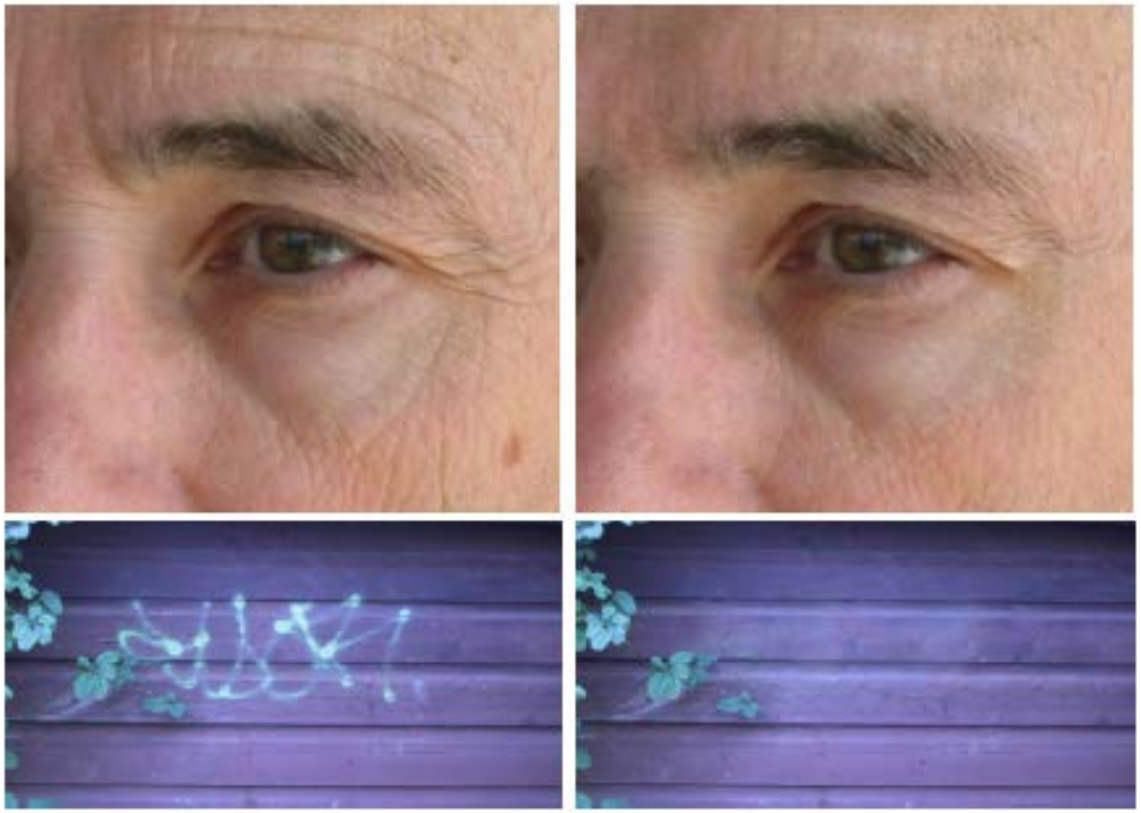


Figure 2: **Concealment**. By importing seamlessly a piece of the background, complete objects, parts of objects, and undesirable artifacts can easily be hidden. In both examples, multiple strokes (not shown) were used.

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

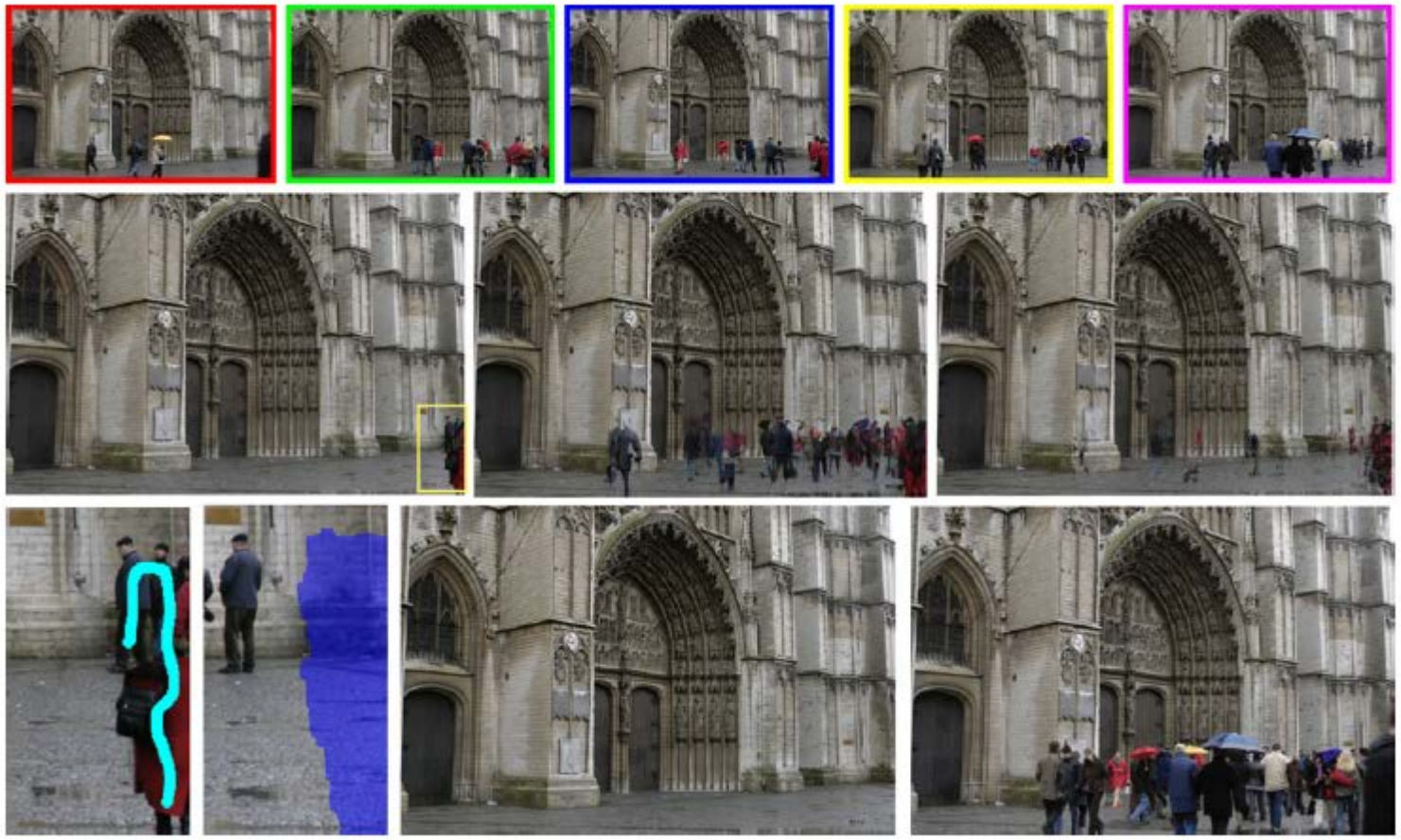
Interactive Digital Photomontage

Aseem Agarwala, Mira Dontcheva
Maneesh Agrawala, Steven Drucker, Alex Colburn
Brian Curless, David Salesin, Michael Cohen

Interactive Digital Photomontage

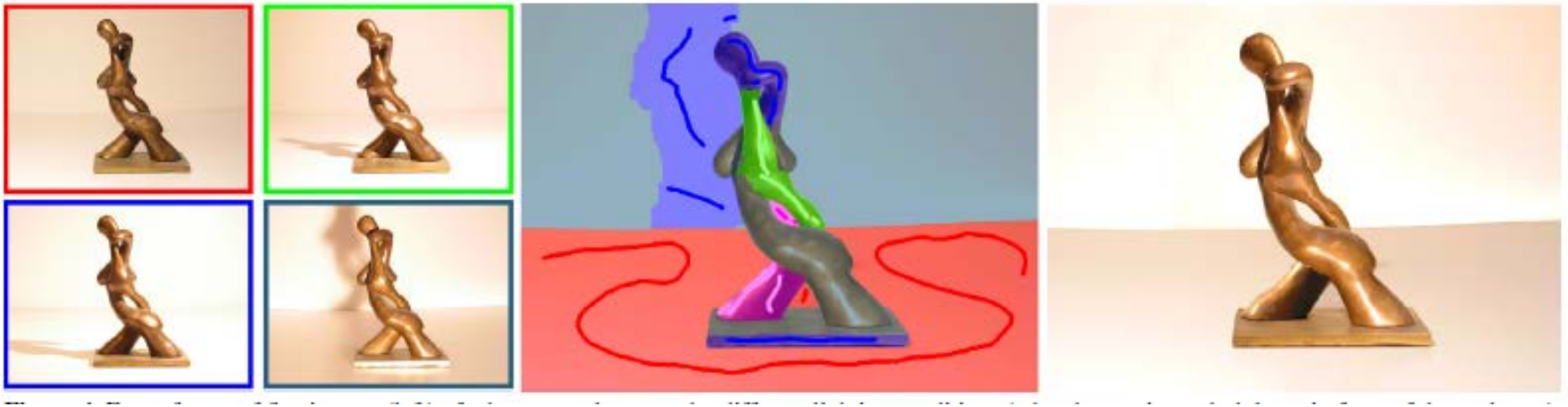
Agarwala et al. SIGGRAPH 04

Interactive Digital Photomontage



Agarwala et al. SIGGRAPH 04

Interactive Digital Photomontage

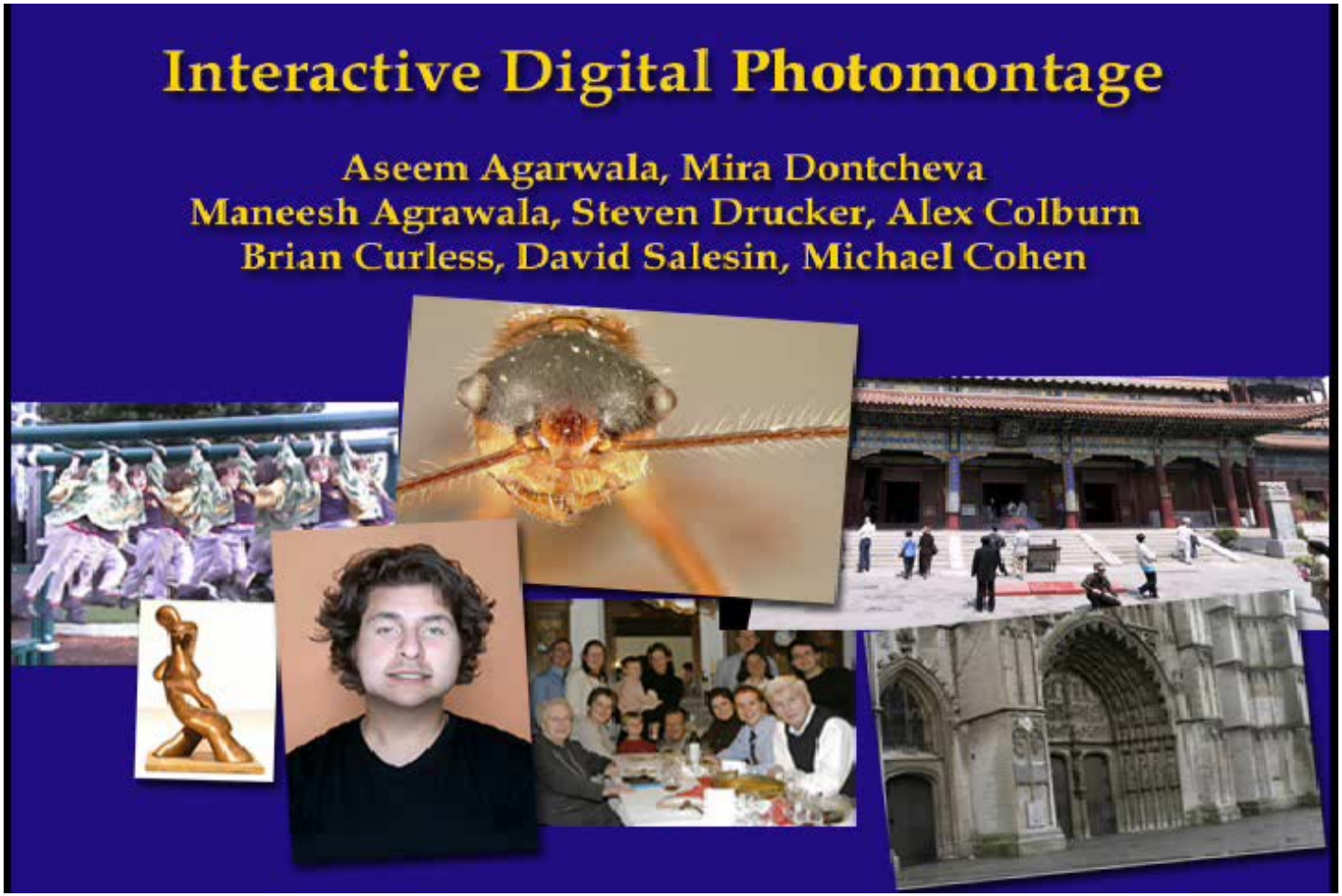


Agarwala et al. SIGGRAPH 04

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

Motivation

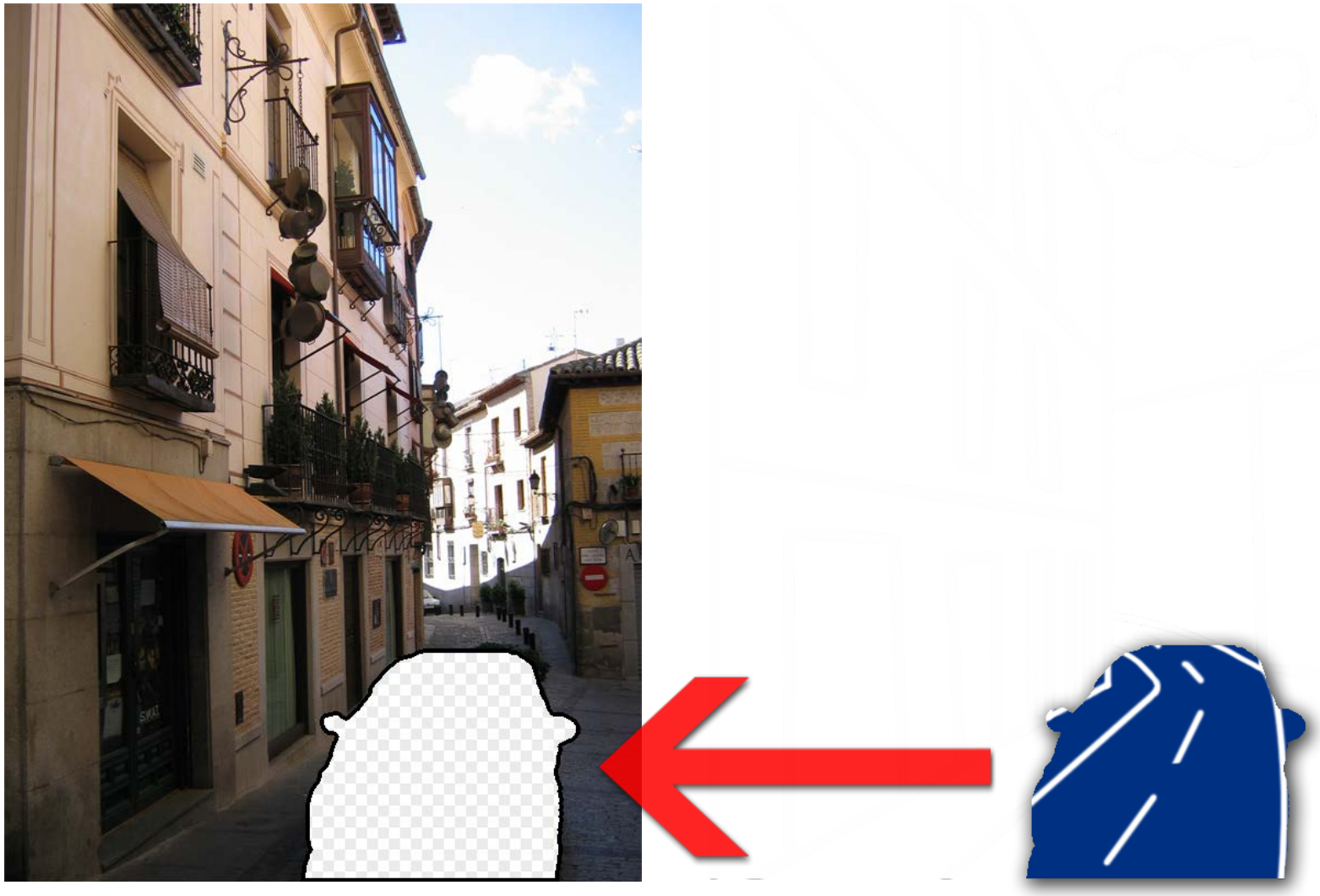
Motivation

Motivation

Texture synthesis (Efros and Leung) result

Scene Matching for Image Completion

Scene Matching for Image Completion



Google

alley

Search Images | Search the Web | Advanced Image Search | Preferences

Strict SafeSearch is on

Images Showing: All image sizes

Results **1** - **20** of about **908,000** for **alley** [definition] with **Safesearch on**. (**0.07** seconds)

Change **Alley** Aerial Plaza with its **...**
300 x 400 - 21k
en.wikipedia.org

The Printer's **Alley** sign looking **...**
679 x 450 - 469k - jpg
franklin.thefuntimesguide.com

Looking west past Printers **Alley**.
679 x 450 - 464k - jpg
franklin.thefuntimesguide.com

More Bubble Gum **Alley** photos can be **...**
764 x 591 - 33k - gif
www.locallinks.com

Gasoline **Alley** gang
692 x 430 - 177k - jpg
newcritics.com

2007 **Alley** Loop Sponsors
300 x 453 - 51k - jpg
www.cbnordic.org

Change **Alley** : interior
550 x 413 - 98k
infopedia.nlb.gov.sg

Earl G. **Alley ...**
321 x 383 - 19k - jpg
www.msstate.edu

Gun **Alley** 8.5x11 Full Color Ink Wash **...**
390 x 301 - 14k - jpg
www.rorschachentertainment.com

Grace Court **Alley**
732 x 549 - 98k - jpg
www.bridgeandtunnelclub.com

Grace Court **Alley**
732 x 549 - 80k - jpg
www.bridgeandtunnelclub.com

panoramic photo of Alligator **Alley**
4902 x 460 - 1048k - jpg
sflwww.er.usgs.gov

Richard B. **Alley**
450 x 361 - 29k - gif
www.ncdc.noaa.gov

Also, Chicken **Alley** is reported to **...**
450 x 337 - 82k
phidoux.typepad.com

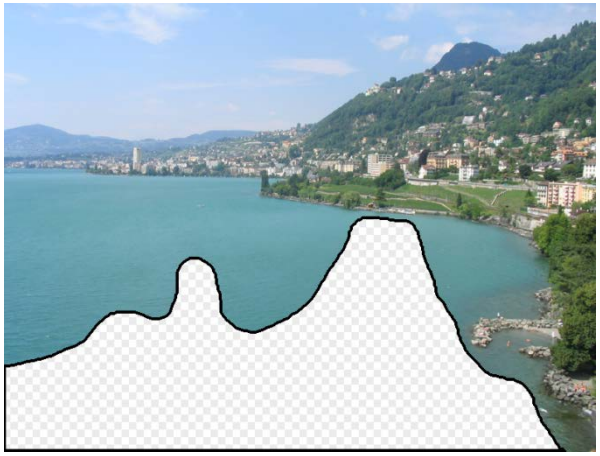
Ego **Alley**
500 x 375 - 48k - jpg
dc.about.com

Data

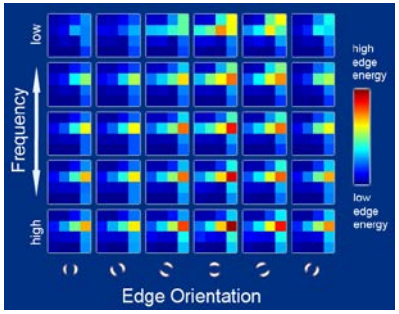
2.3 Million unique images from Flickr groups and keyword searches.

Scene Completion Result

The Algorithm



Input image



Scene Descriptor

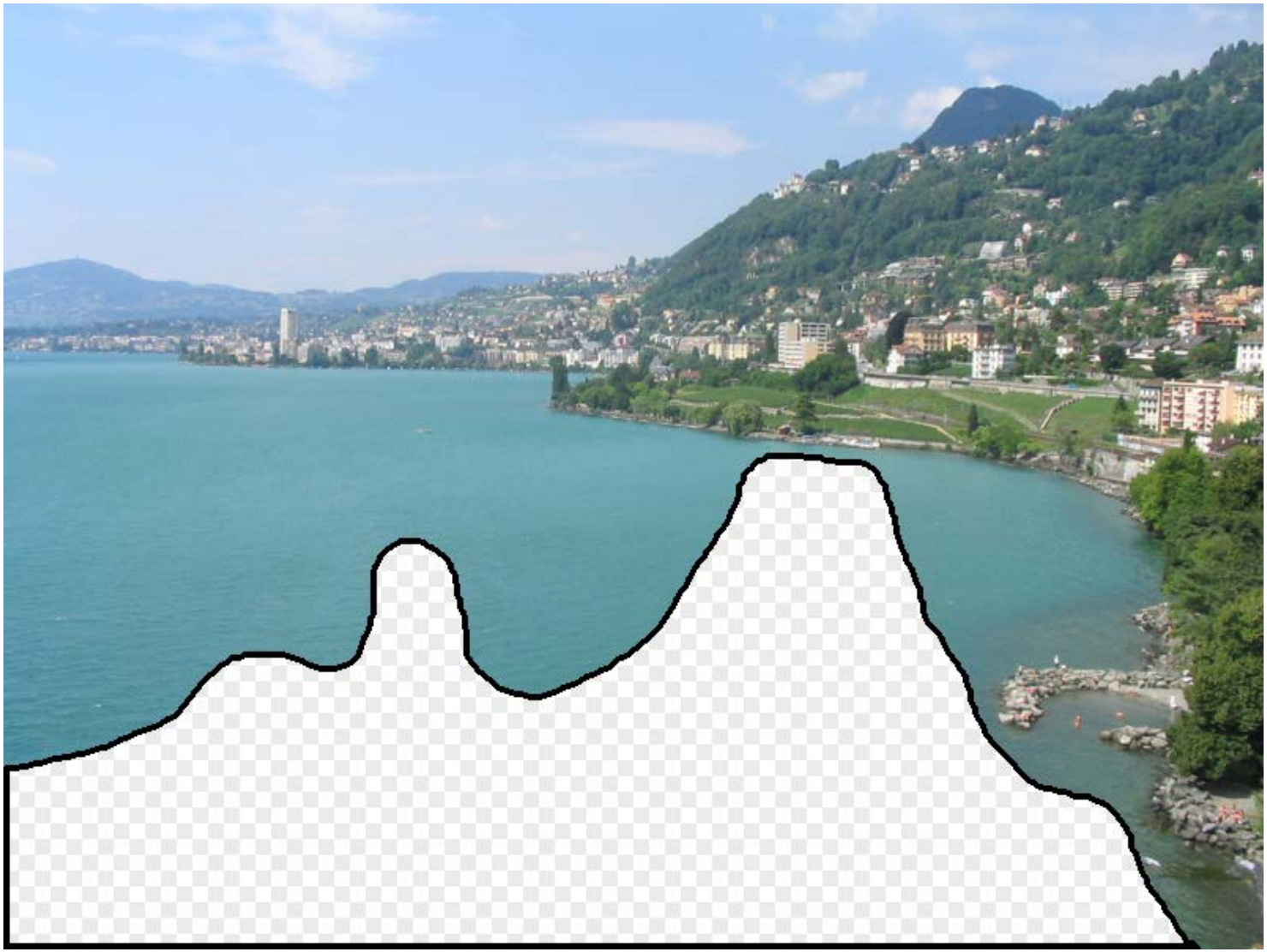
Image Collection

200 matches

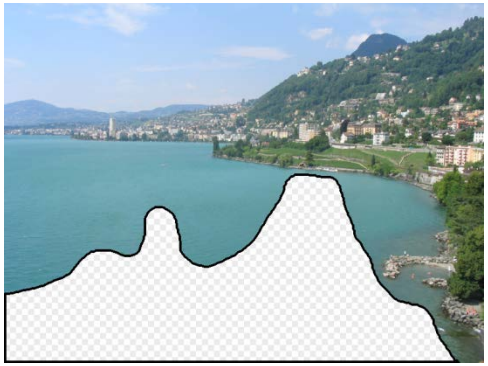
Context + blending

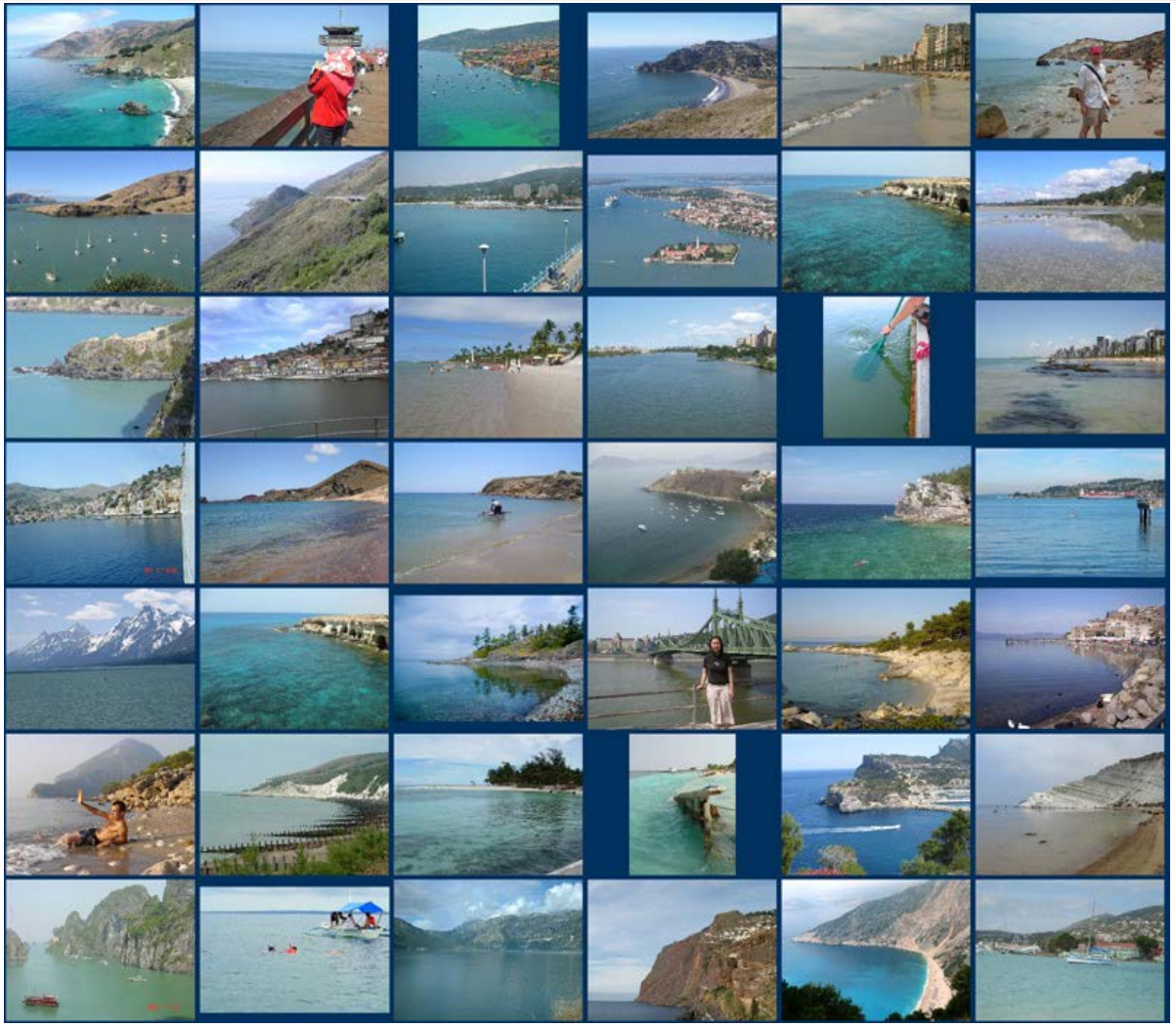
20 completions

Scene Matching



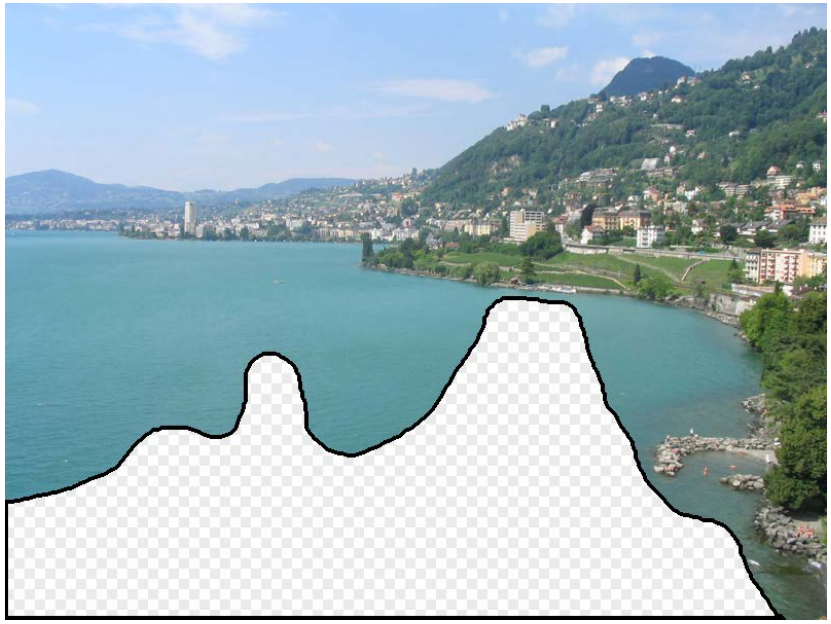
Scene Matching





… 200 total

Context Matching



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