CS354 Computer Graphics
Computational Photography

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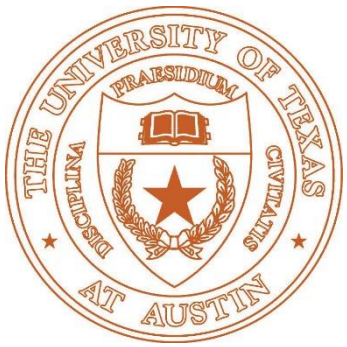
April 23th 2018



Background

- Sales of digital cameras surpassed sales of film cameras in 2004

Digital Cameras

- Free film
- Instant display
- Quality surpass film
- Records metadata
  - Shooting parameters, camera location&orientation

Digital cameras

- Same experience as film cameras
  - Set zoom and focus
  - Set aperture and exposure
  - Press shutter to take a single picture

- Essentially, film camera with bits (0/1)?

Computational Photography: Definition

- Computational techniques that enhance or extend the capabilities of digital photography

- Output is an ordinary photographs, but one that could not have been taken by a traditional camera

Computational Photography: an Interdisciplinary Field

- Computer Graphics
- Computer Vision
- Image Processing
- Signal Processing
- Optics
- Embedded Systems

Digital Photography

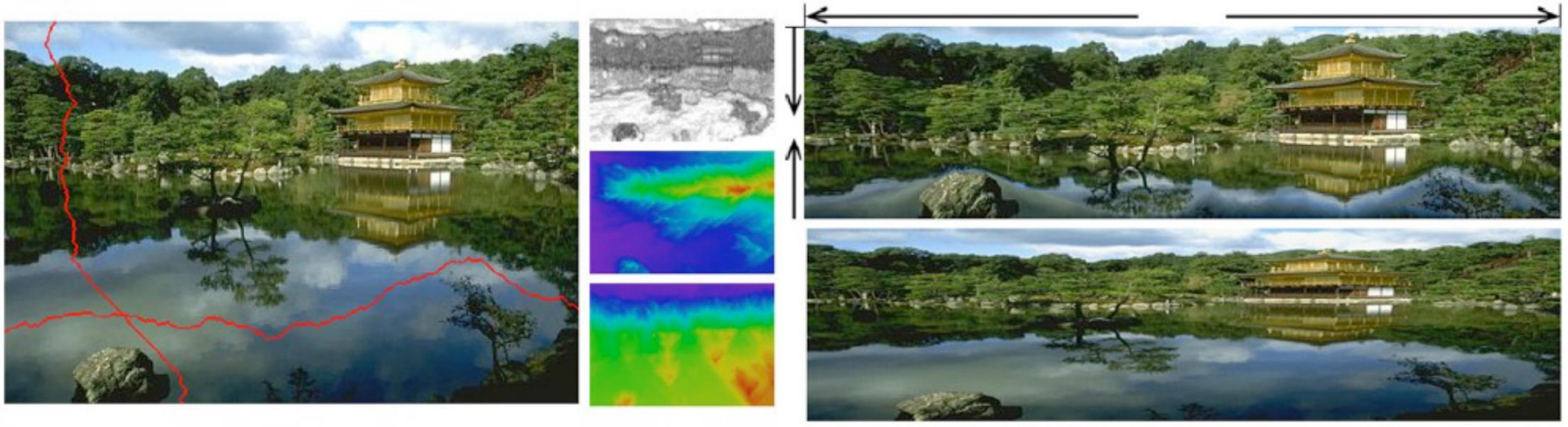
Digital Photography

- Image processing applied to captured images to produce better images

- Examples: Interpolation, Filtering, Enhancement, Dynamic Range Compression, Color Management, Morphing, Hole Filling, Artistic Image Effects, Image Compression, Watermarking.

Seam Carving for Content-Aware Image Resizing
Avidan, Shamir (SIGGRAPH 2007)

- To expand: insert pixel along seams that, if removed, will yield original image



Seam Carving for Content-Aware Image Resizing
Avidan, Shamir (SIGGRAPH 2007)

- To contract: remove pixels along the lowest-energy seams, found with dynamic programming
- Object removal for an application?

A Bayesian Approach to Digital Matting
Chuang et al. (CVPR 2001)

- Generate local color model for foreground, background
- Probabilistically assign alpha to unclassified pixels

Removing Camera Shake from a Single Image
Fergus et al. (SIGGRAPH 2006)

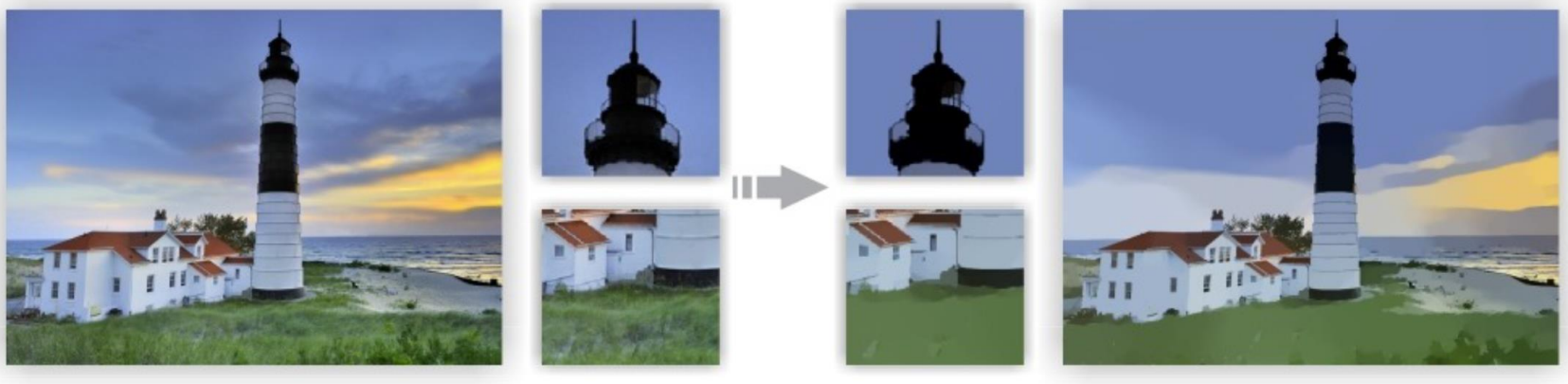
Fast Motion Deblurring
Cho, Lee (SIGGRAPH Asia 2009)

Input blurred image | Deblurring result | Magnified views

Local Laplacian Filters: Edge-aware Image Processing with a Laplacian Pyramid
Paris, Hasinoff, Kautz (SIGGRAPH 2011)

- Image Smoothing via L0 Gradient Minimization

  Xu et al. (SIGGRAPH Asia 2011)



Computational Processing

Computational Processing

- Processing of a set of captured images to create new images

- Examples:
  - Mosaicing, Matting, Super-Resolution, Multi-Exposure HDR, Light Field from, Multiple View, Structure from Motion, Shape from X.

Interative Digital Photomontage
Agarwala et al. (SIGGRAPH 2004)

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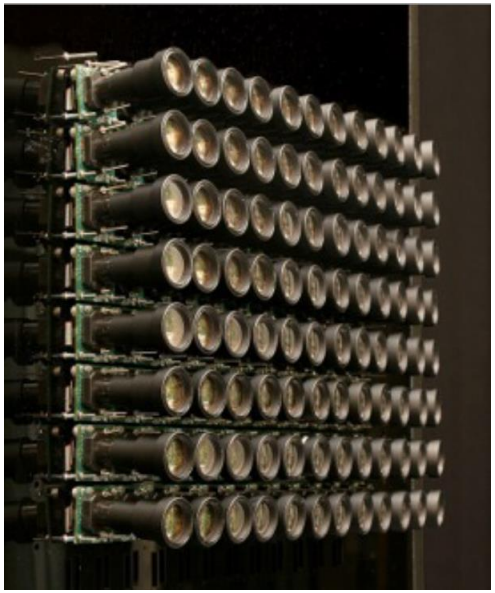
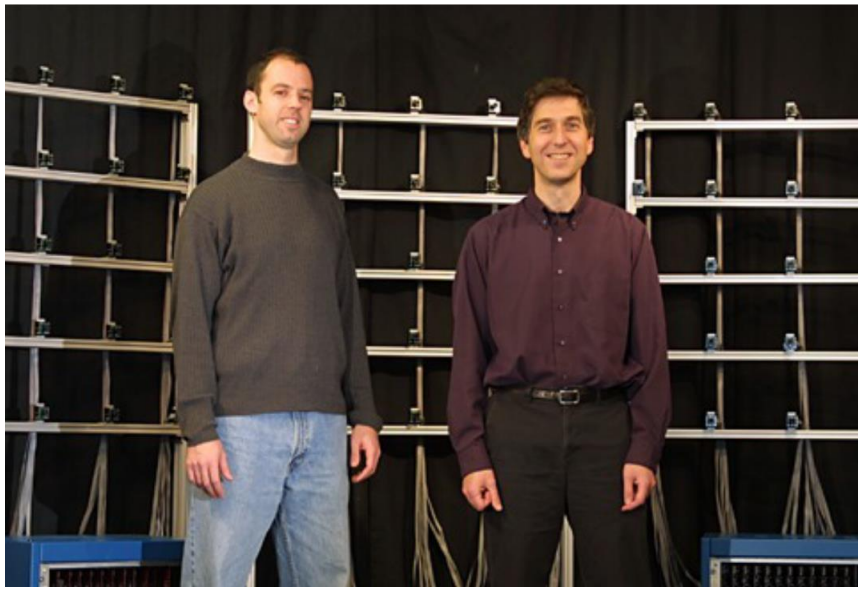
Interactive Digital Photomontage
Agarwala et al. (SIGGRAPH 2004)

High Performance Imaging using Large Camera Arrays
Wilburn et al. (SIGGRAPH 2005)

640 x 480 pixels x
30 fps x 128 cameras

synchronized timing
continuous streaming
flexible arrangement





High Performance Imaging using Large Camera Arrays
Wilburn et al. (SIGGRAPH 2005)

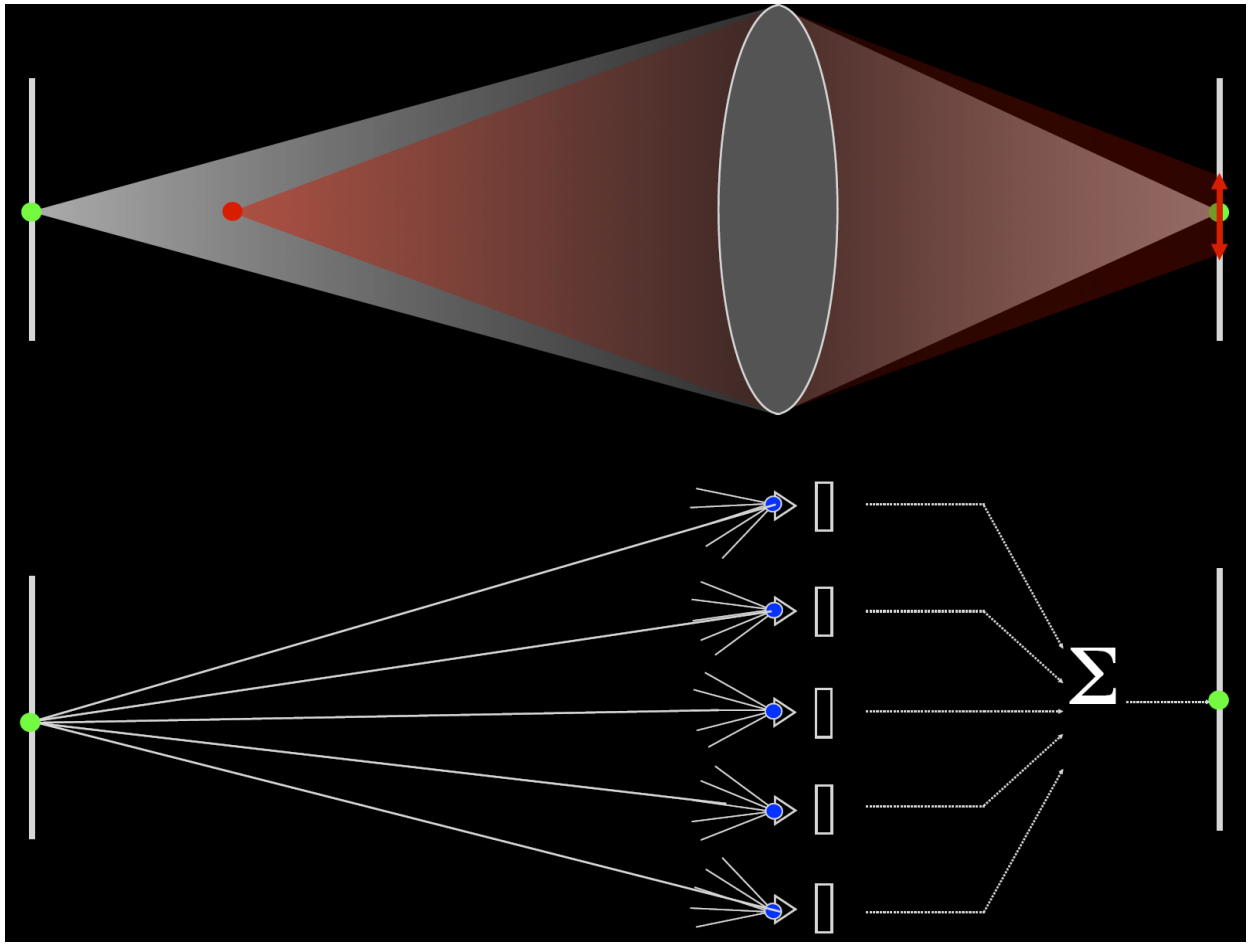
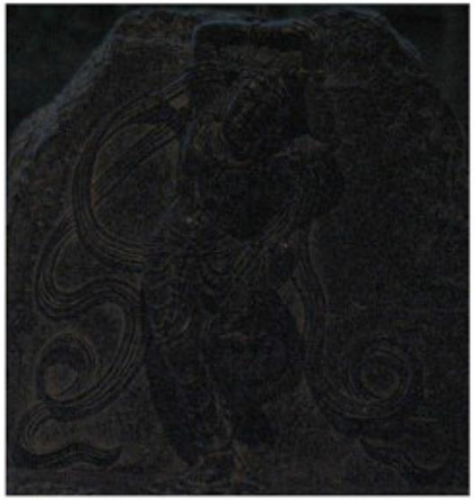


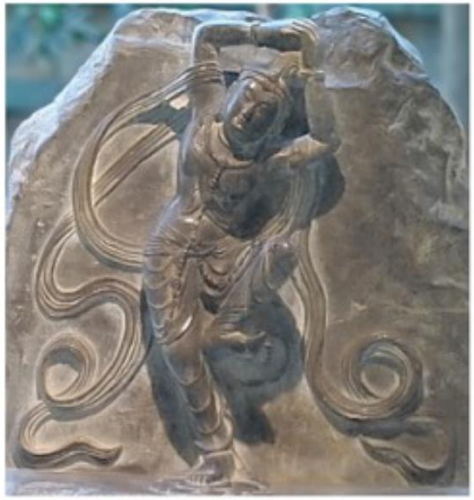
Image Deblurring with Blurry/Noisy Image Pairs
Yuan et al. (SIGGRAPH 2007)

long exposure
(blurry)



short exposure
(dark)

same, scaled up
(noisy)



joint
deconvolution

Other Interesting Topics

Bilateral Filtering

$$I^{\text{filtered}}(x) = \frac{1}{W_p} \sum_{x_i \in \Omega} I(x_i) f_r(\|I(x_i) - I(x)\|) g_s(\|x_i - x\|)$$

$$W_p = \sum_{x_i \in \Omega} f_r(\|I(x_i) - I(x)\|) g_s(\|x_i - x\|)$$

$$w(i,j,k,l) = \exp\left(-\frac{(i-k)^2 + (j-l)^2}{2\sigma_d^2} - \frac{\|I(i,j) - I(k,l)\|^2}{2\sigma_r^2} \right)$$

$$I_D(i,j) = \frac{\sum_{k,l} I(k,l) w(i,j,k,l)}{\sum_{k,l} w(i,j,k,l)}$$

Standard Filtering

$$J(x) = \sum_{\xi} f(x,\xi)\, I(\xi)$$

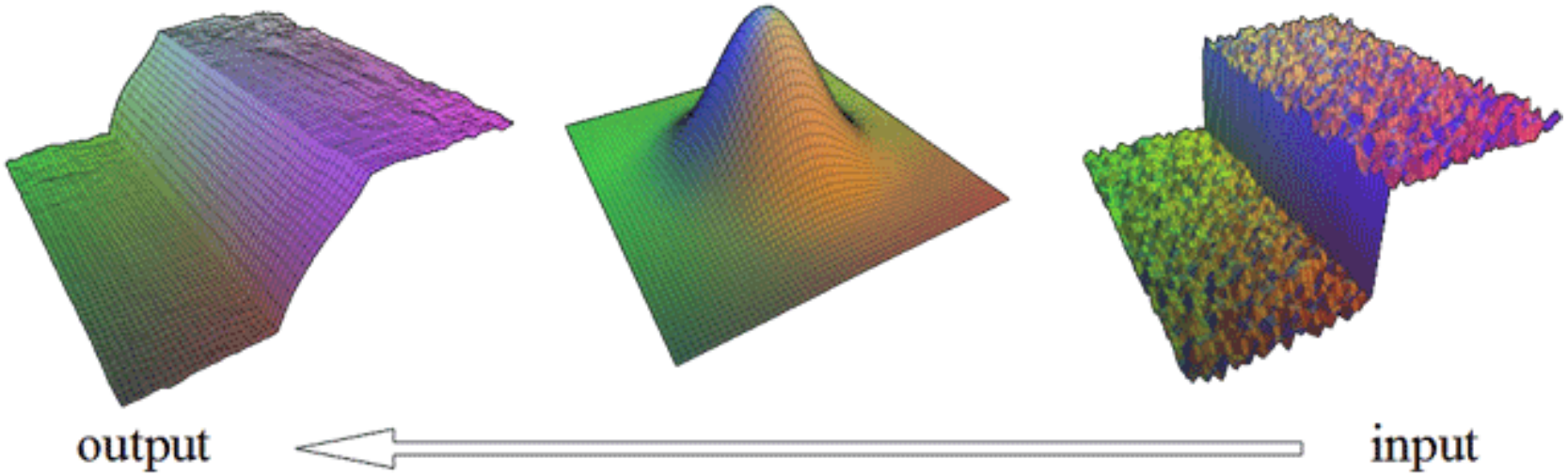


Image from http://www.cmlab.csie.ntu.edu.tw/~zho/Bilateral/html-data/equ02.png

Bilateral Filtering

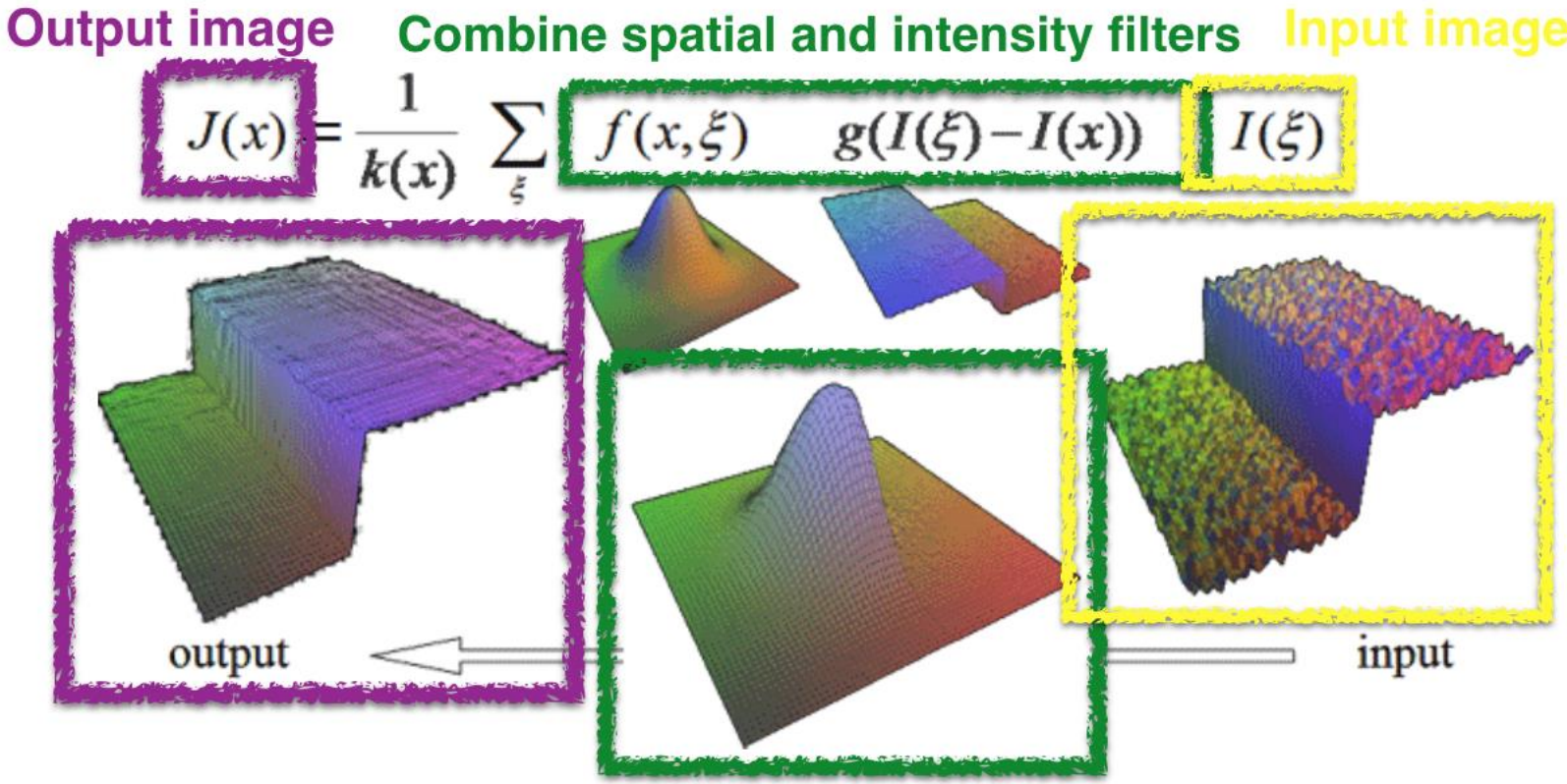


Image from http://www.cmlab.csie.ntu.edu.tw/~zho/Bilateral/html-data/equ03.png

PatchMatch

[Barnes et al. 2009]

PatchMatch: A Randomized Correspondence Algorithm for Structural Image Editing

Connelly Barnes[1] Eli Shechtman[2,3] Adam Finkelstein[1] Dan B Goldman[2]
[1]Princeton University [2]Adobe Systems [3]University of Washington

(a) original (b) hole+constraints (c) hole filled (d) constraints (e) constrained retarget (f) reshuffle

Figure 1: *Structural image editing. Left to right: (a) the original image; (b) a hole is marked (magenta) and we use line constraints (red/green/blue) to improve the continuity of the roofline; (c) the hole is filled in; (d) user-supplied line constraints for retargeting; (e) retargeting using constraints eliminates two columns automatically; and (f) user translates the roof upward using reshuffling.*

PatchMatch
[Barnes et al. 2009]

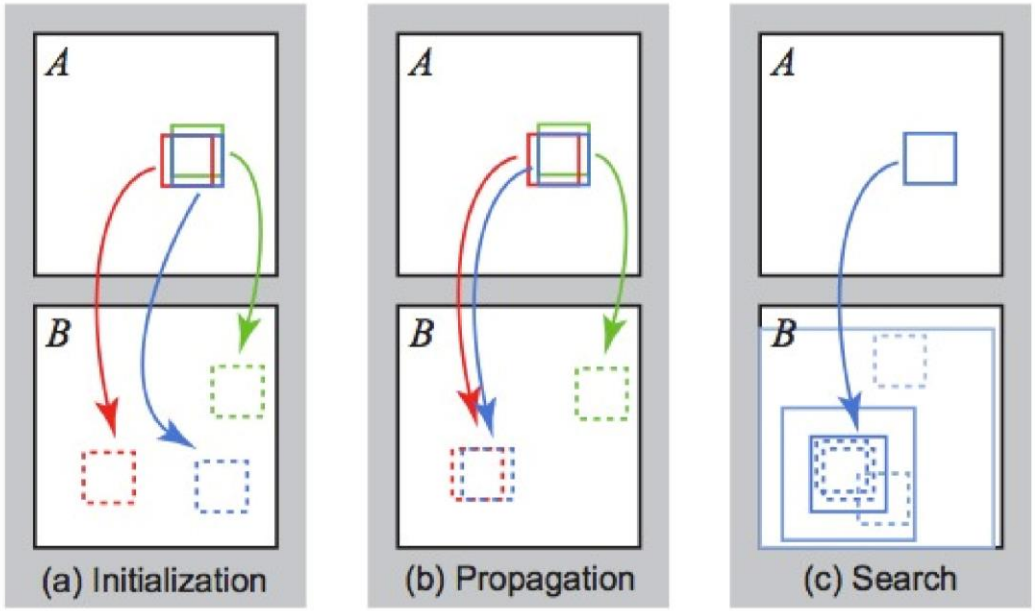
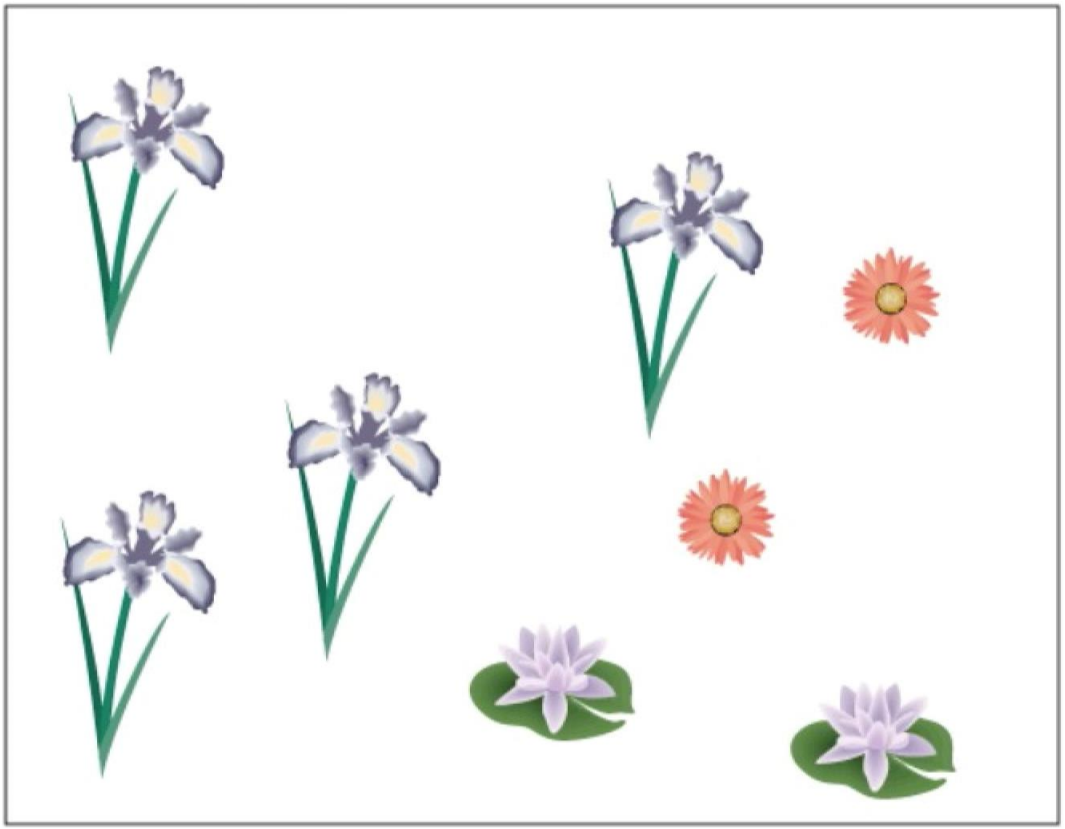
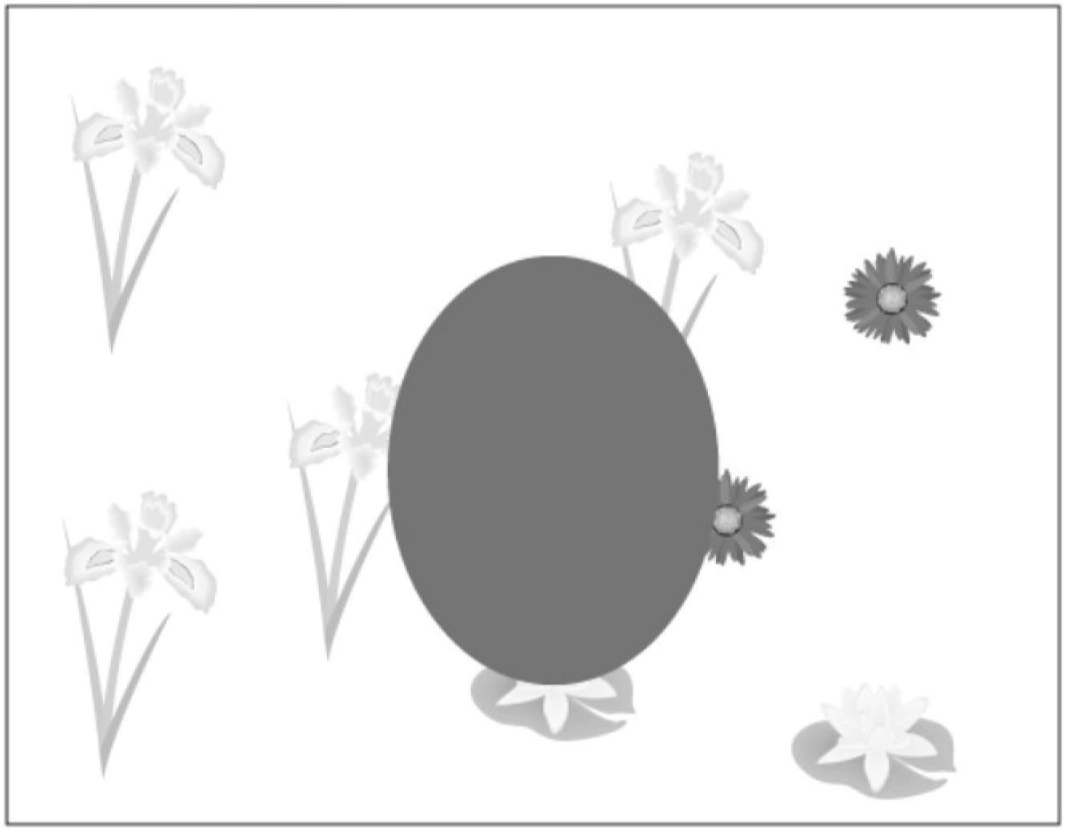


Figure 2: *Phases of the randomized nearest neighbor algorithm: (a) patches initially have random assignments; (b) the blue patch checks above/green and left/red neighbors to see if they will improve the blue mapping, propagating good matches; (c) the patch searches randomly for improvements in concentric neighborhoods.*

PatchMatch
[Barnes et al. 2009]



PatchMatch
[Barnes et al. 2009]



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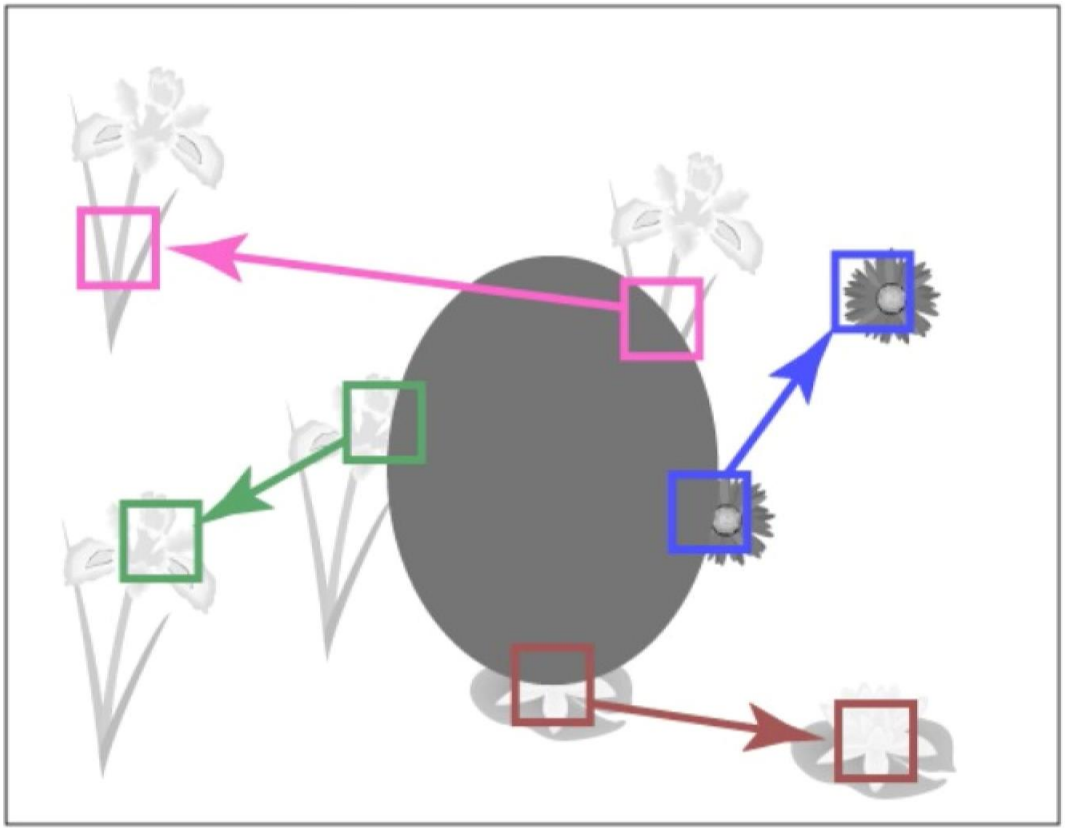
[Barnes et al. 2009]



Scene Completion
[Hays and Efros 2007]

Scene Completion Using Millions of Photographs

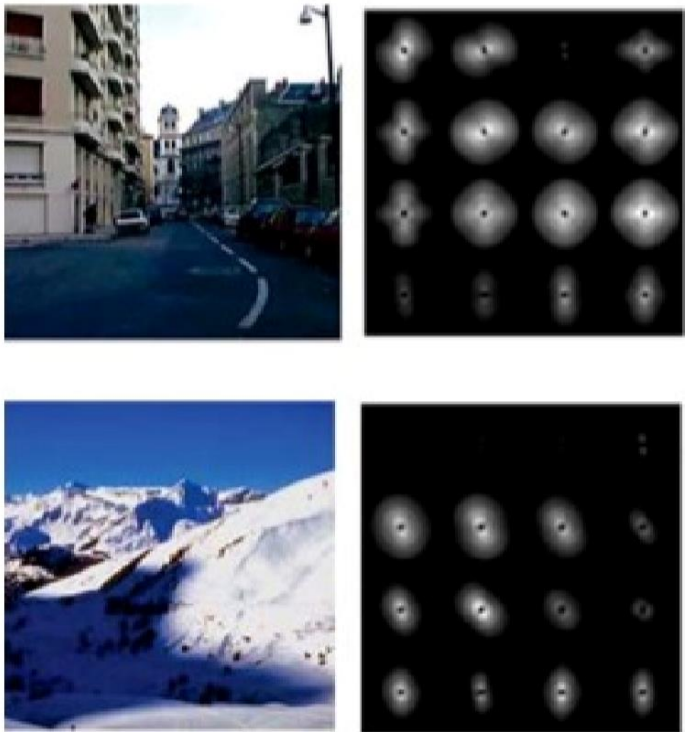
James Hays Alexei A. Efros
Carnegie Mellon University

Original Image Input Scene Matches Output

Figure 1: Given an input image with a missing region, we use matching scenes from a large collection of photographs to complete the image.

Scene Completion

- GIST [Oliva and Torralba 2006] encodes scene semantics
- Histograms of oriented edge filter responses in coarse spatial bins at multiple scales
- Only works for semantic matching with HUGE datasets



Scene Completion

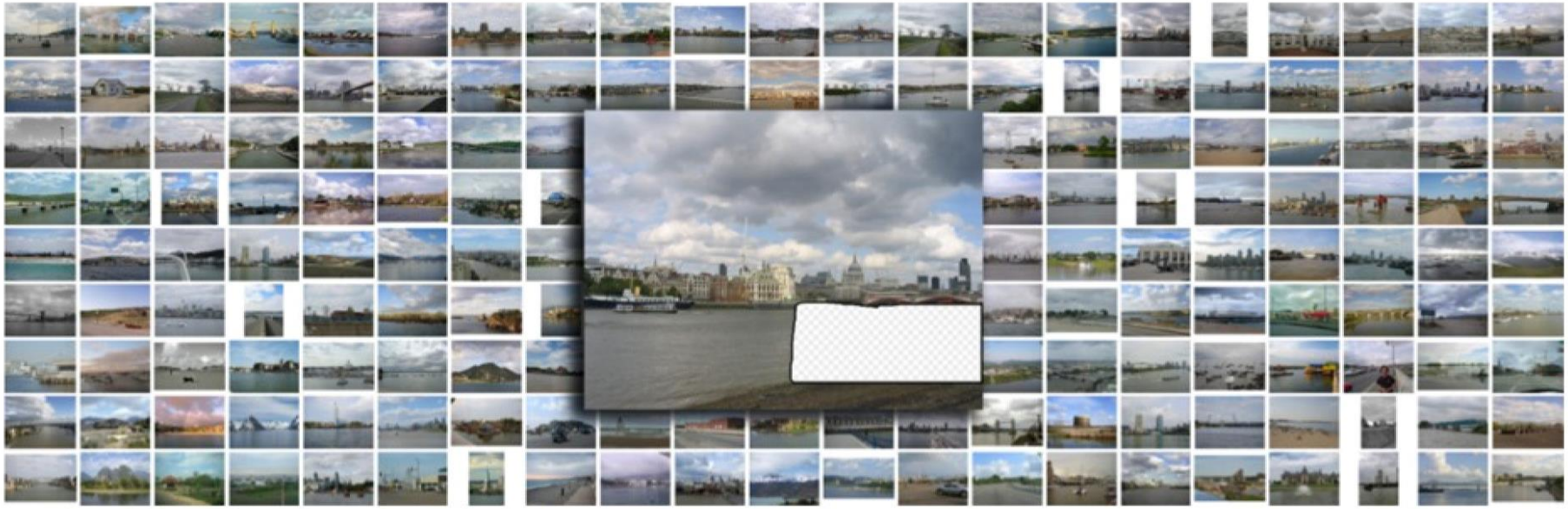
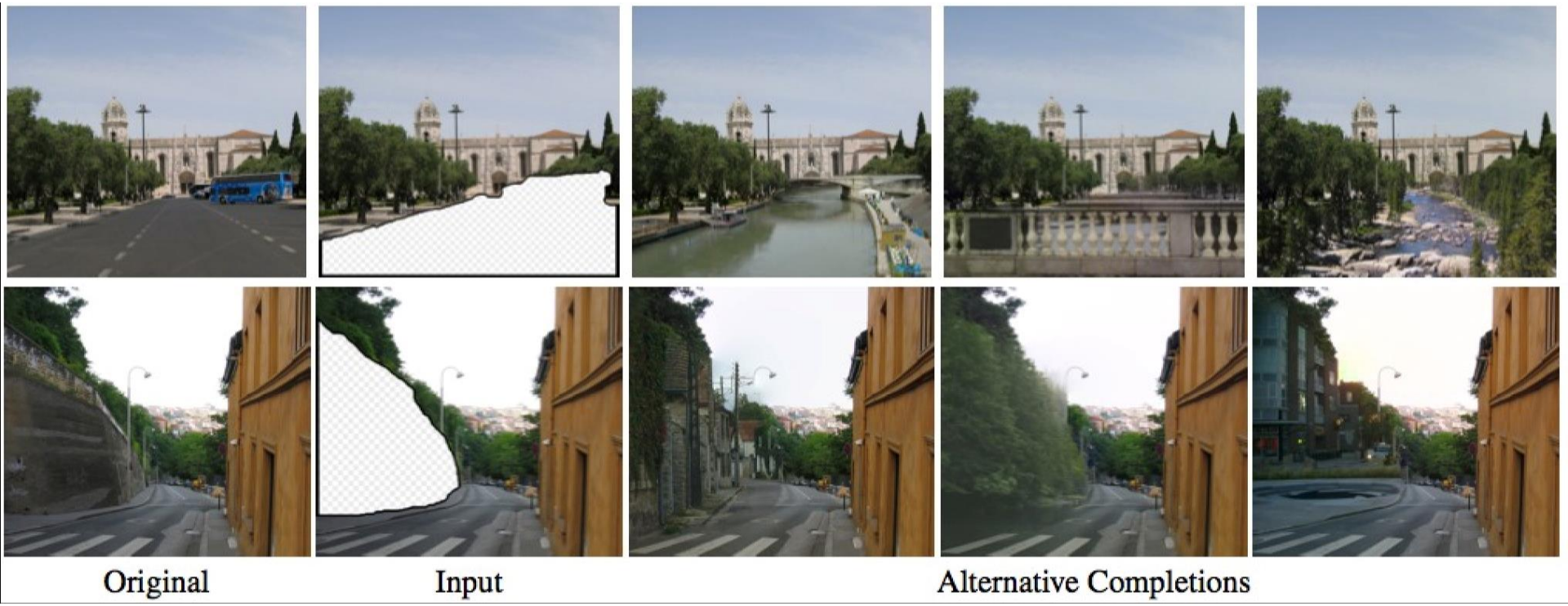


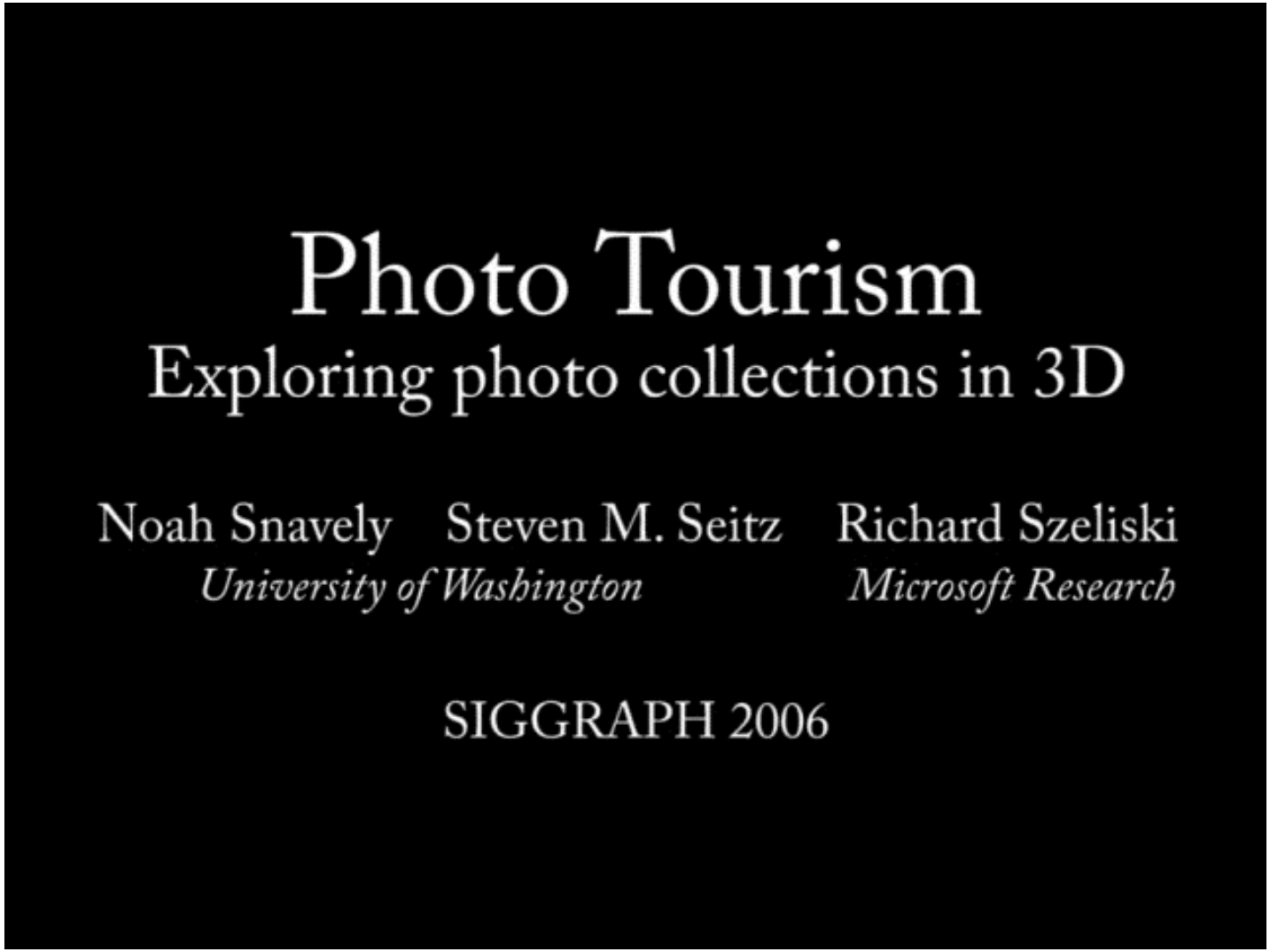
Figure 3: The 164 closest scenes to the incomplete image in the center. Most of the scenes are semantically and structurally similar; many are even from the same city (London).

- Show top N choices to user
- Composite using Graphcut and Poisson blending

Scene Completion



Phototourism



Next Lecture

- Computational Imaging/Optics
- Computational Sensor
- Computational Illumination

Discussion