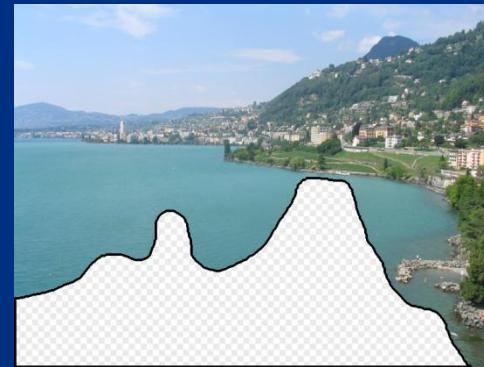


# Scene Completion Using Millions of Photographs



SIGGRAPH2007



James Hays and Alexei A. Efros

Carnegie Mellon University





Hays and Efros, SIGGRAPH 2007



Hays and Efros, SIGGRAPH 2007



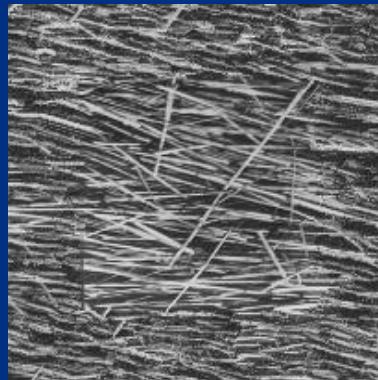
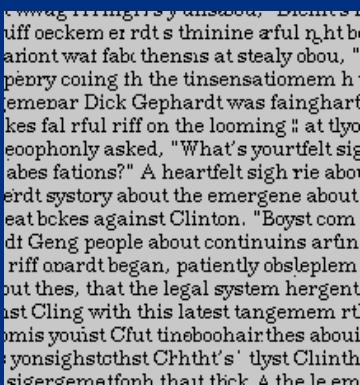
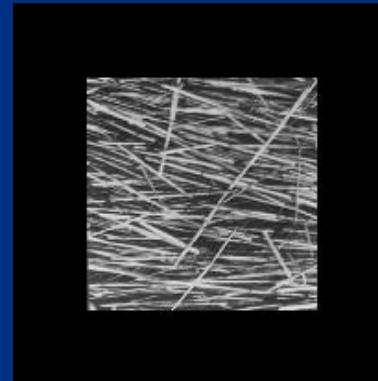
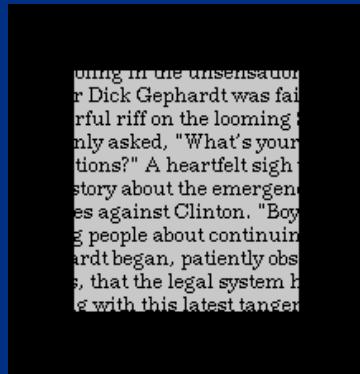
Since 1699, when French explorers landed at the great bend of the Mississippi River and celebrated the first Mardi Gras in North America, New Orleans has brewed a fascinating mélange of cultures. It was French, then Spanish, then French again, then sold to the United States. Through all these years, and even into the 1900s, others arrived from everywhere: Acadians (Cajuns), Africans, indige-



Bertalmio, Sapiro, Caselles, and Ballester.  
Image Inpainting. SIGGRAPH 2000.



# Diffusion Result

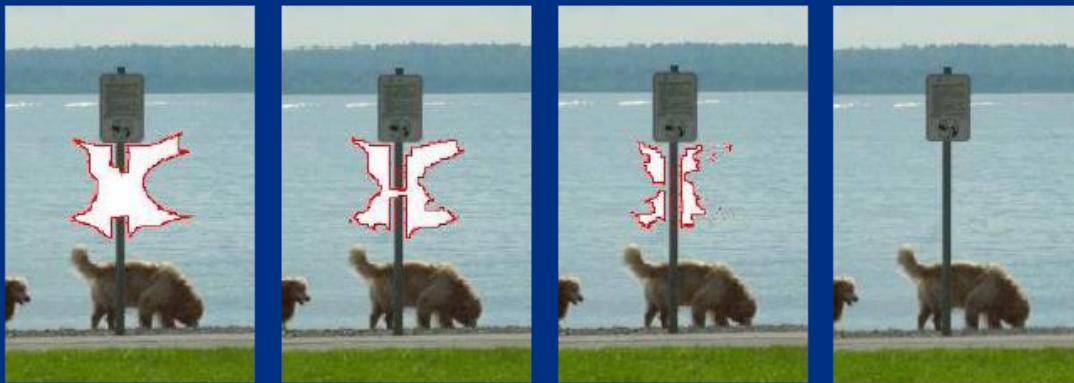


Efros and Leung. Texture synthesis by non-parametric sampling. ICCV 1999.



## Efros and Leung result

Hays and Efros, SIGGRAPH 2007



Criminisi, Perez, and Toyama. Region filling and object removal by exemplar-based inpainting.  
IEEE Transactions on Image Processing. 2004.



Criminisi et al. result

Hays and Efros, SIGGRAPH 2007



Criminisi et al. result

Hays and Efros, SIGGRAPH 2007



Microsoft Digital Image Pro Smart erase result

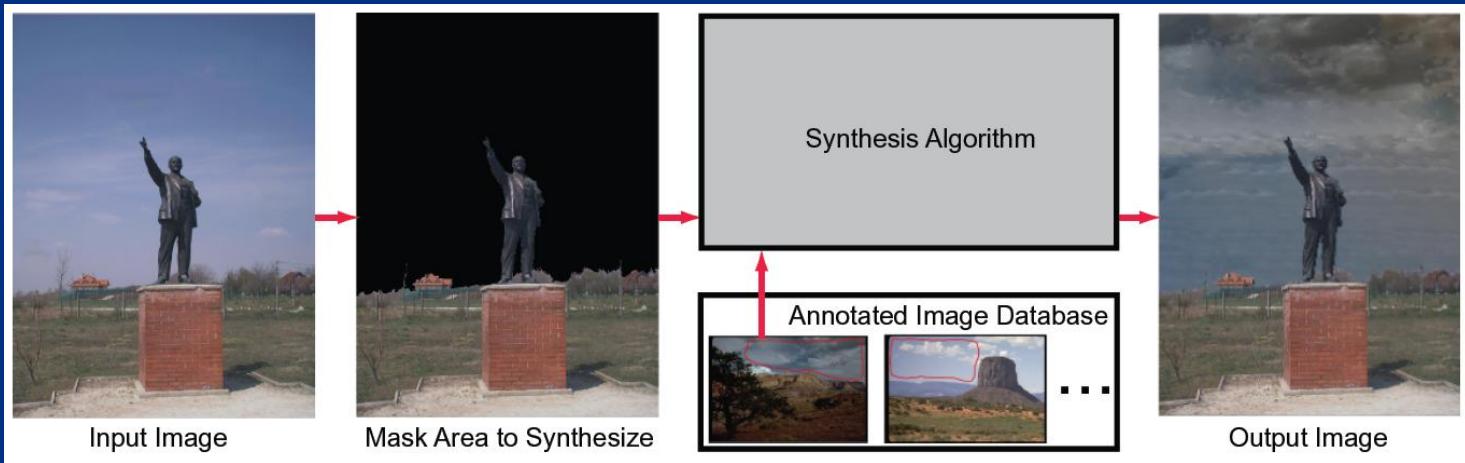
Hays and Efros, SIGGRAPH 2007



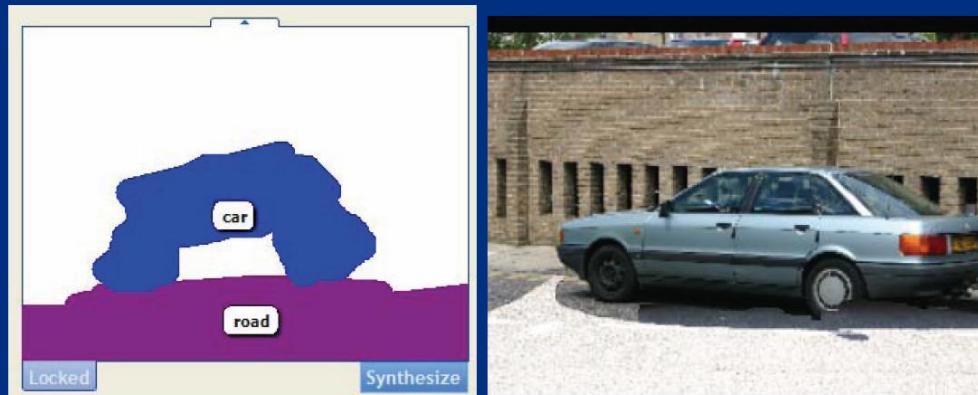
Hays and Efros, SIGGRAPH 2007



Road



Diakopoulos, Essa, Jain. Content Based Image Synthesis. Conference on Image and Video Retrieval (CIVR) 2004.



Johnson, Brostow, Shotton, Arandjelovic, Kwatra, and Cipolla. Semantic Photo Synthesis. Eurographics 2006.



Jian Sun, Lu Yuan, Jiaya Jia and Heung-Yeung Shum.  
Image Completion with Structure Propagation. SIGGRAPH 2005

Hays and Efros, SIGGRAPH 2007



Jian Sun, Lu Yuan, Jiaya Jia and Heung-Yeung Shum.  
Image Completion with Structure Propagation. SIGGRAPH 2005

Hays and Efros, SIGGRAPH 2007



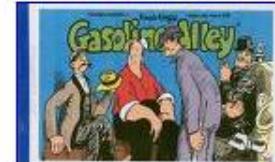
Hays and Efros, SIGGRAPH 2007

# Scene Matching for Image Completion



**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 The Printer's Alley sign looking ... Looking west past Printers Alley.

679 x 450 - 469k - jpg

[franklin.thefuntimesguide.com](http://franklin.thefuntimesguide.com)

679 x 450 - 464k - jpg

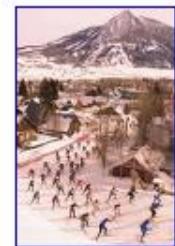
[franklin.thefuntimesguide.com](http://franklin.thefuntimesguide.com)

More Bubble Gum Alley photos can be ...

764 x 591 - 33k - gif

[www.locallinks.com](http://www.locallinks.com)

300 x 400 - 21k  
[en.wikipedia.org](http://en.wikipedia.org)



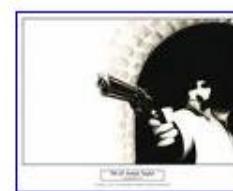
2007 Alley Loop Sponsors  
300 x 453 - 51k - jpg  
[www.cbnordic.org](http://www.cbnordic.org)



Change Alley : interior  
550 x 413 - 98k  
[infopedia.nlb.gov.sg](http://infopedia.nlb.gov.sg)



Earl G. Alley ...  
321 x 383 - 19k - jpg  
[www.msstate.edu](http://www.msstate.edu)



Gun Alley 8.5x11 Full Color Ink Wash ...  
390 x 301 - 14k - jpg  
[www.rorschachentertainment.com](http://www.rorschachentertainment.com)



Grace Court Alley  
732 x 549 - 98k - jpg  
[www.bridgeandtunnelclub.com](http://www.bridgeandtunnelclub.com)



Grace Court Alley  
732 x 549 - 80k - jpg  
[www.bridgeandtunnelclub.com](http://www.bridgeandtunnelclub.com)

panoramic photo of Alligator Alley  
4902 x 460 - 1048k - jpg  
[sflwww.er.usgs.gov](http://sflwww.er.usgs.gov)



Richard B. Alley  
450 x 361 - 29k - gif  
[www.ncdc.noaa.gov](http://www.ncdc.noaa.gov)



Also, Chicken Alley is reported to ...  
450 x 337 - 82k  
[phidoux.typepad.com](http://phidoux.typepad.com)



Ego Alley  
500 x 375 - 48k - jpg  
[dc.about.com](http://dc.about.com)



Hays and Efros, SIGGRAPH 2007



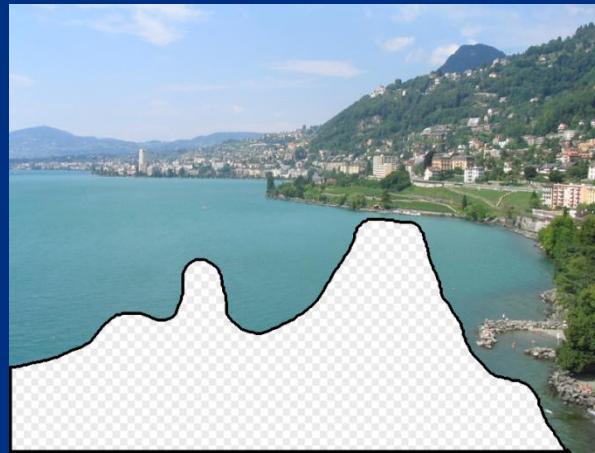
## Scene Completion Result

Hays and Efros, SIGGRAPH 2007

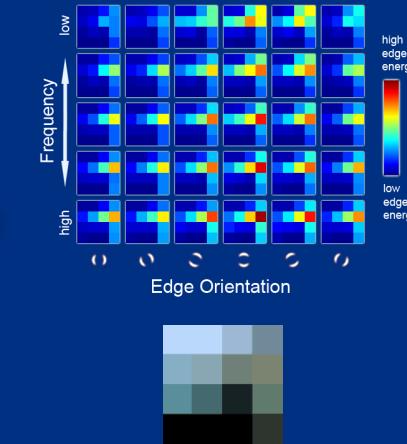


Scene Completion result by Linda Fong

# The Algorithm



Input image



Scene Descriptor



Image Collection



20 completions



Context matching  
+ blending



200 matches

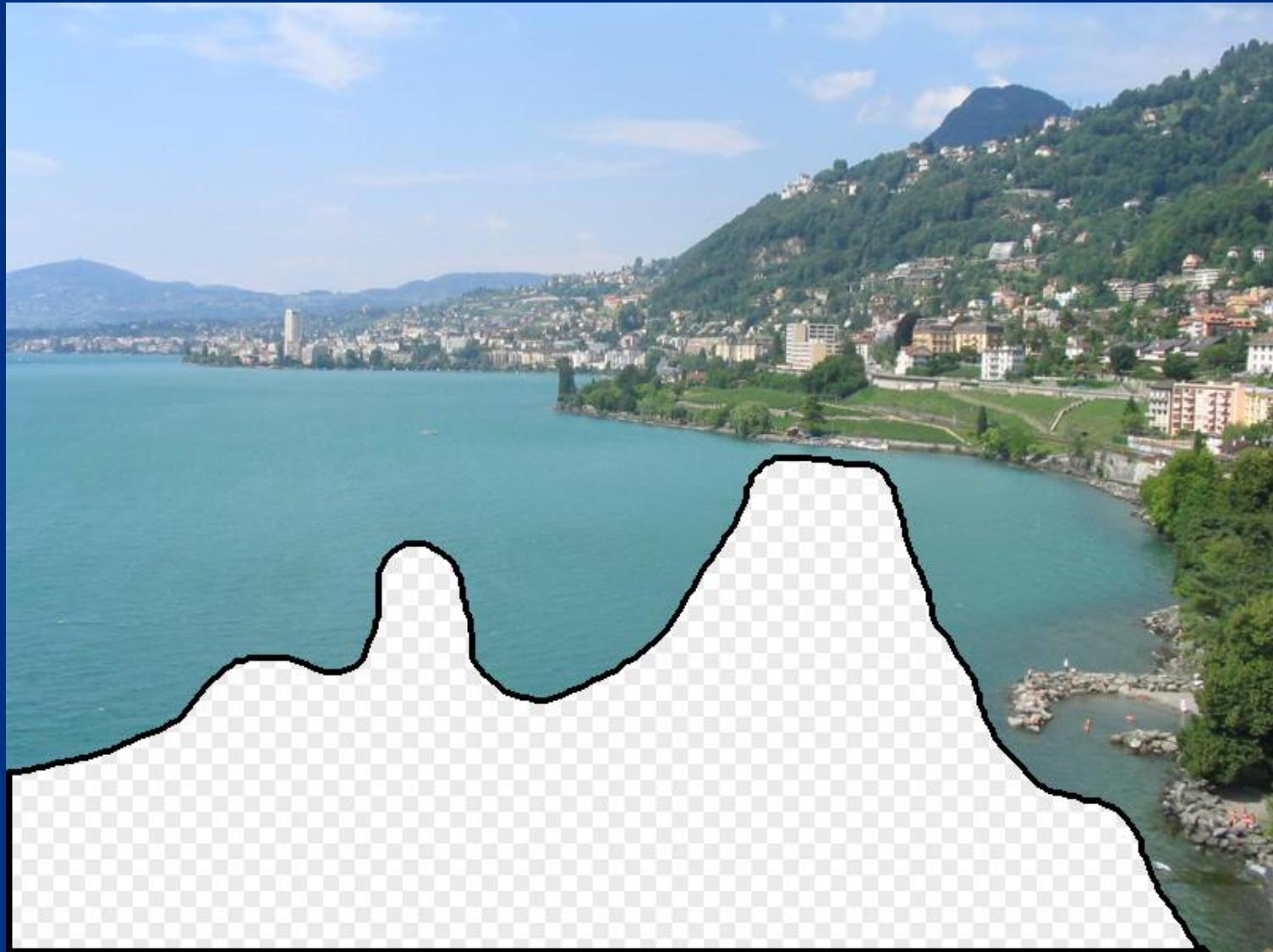
Hays and Efros, SIGGRAPH 2007

# Data

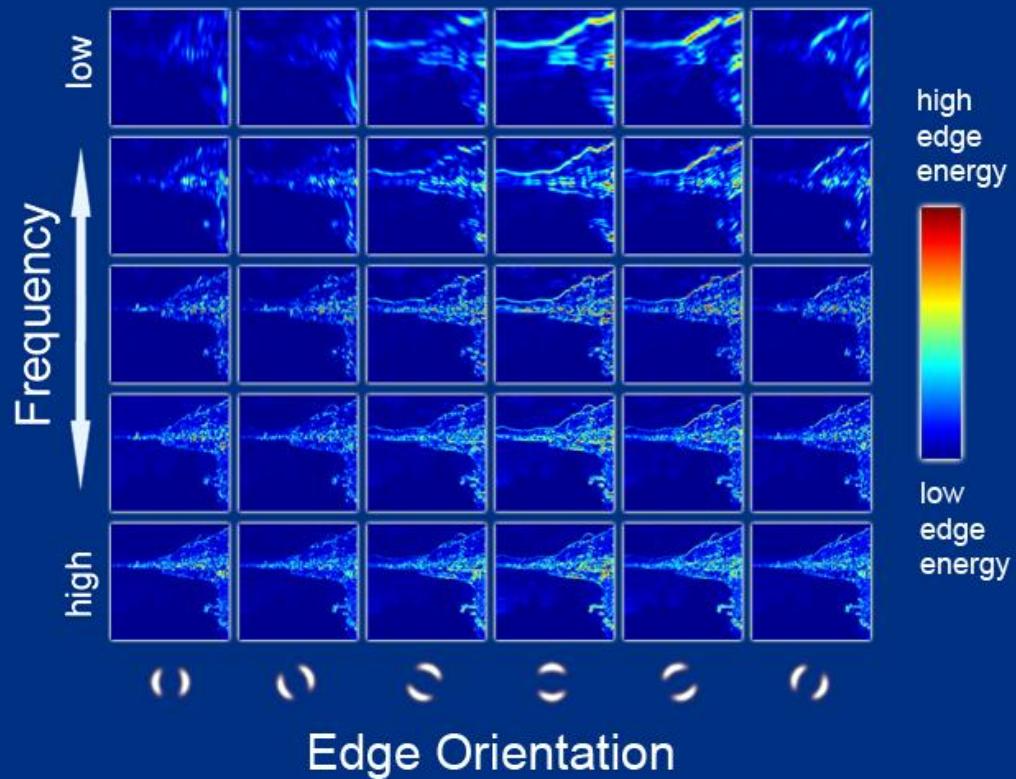
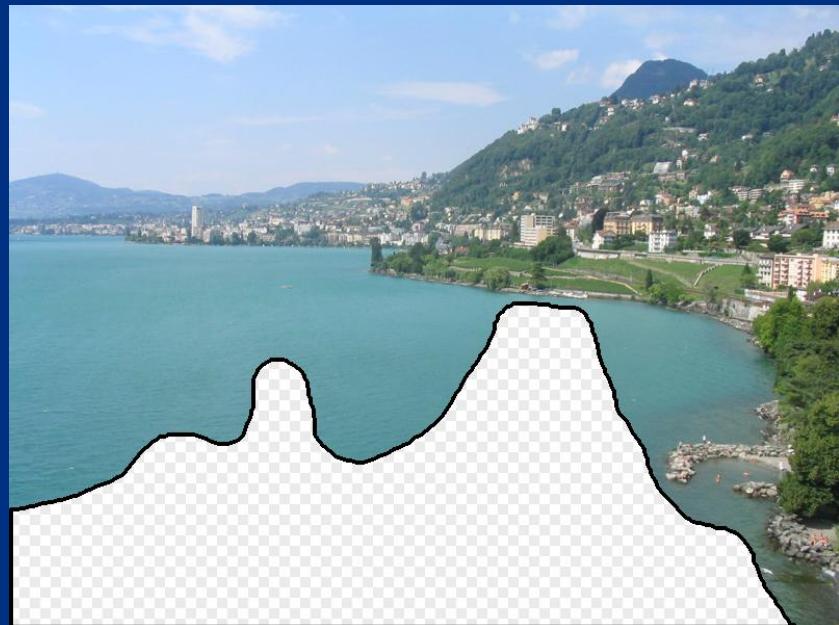
We downloaded **2.3 Million** unique images from Flickr groups and keyword searches.



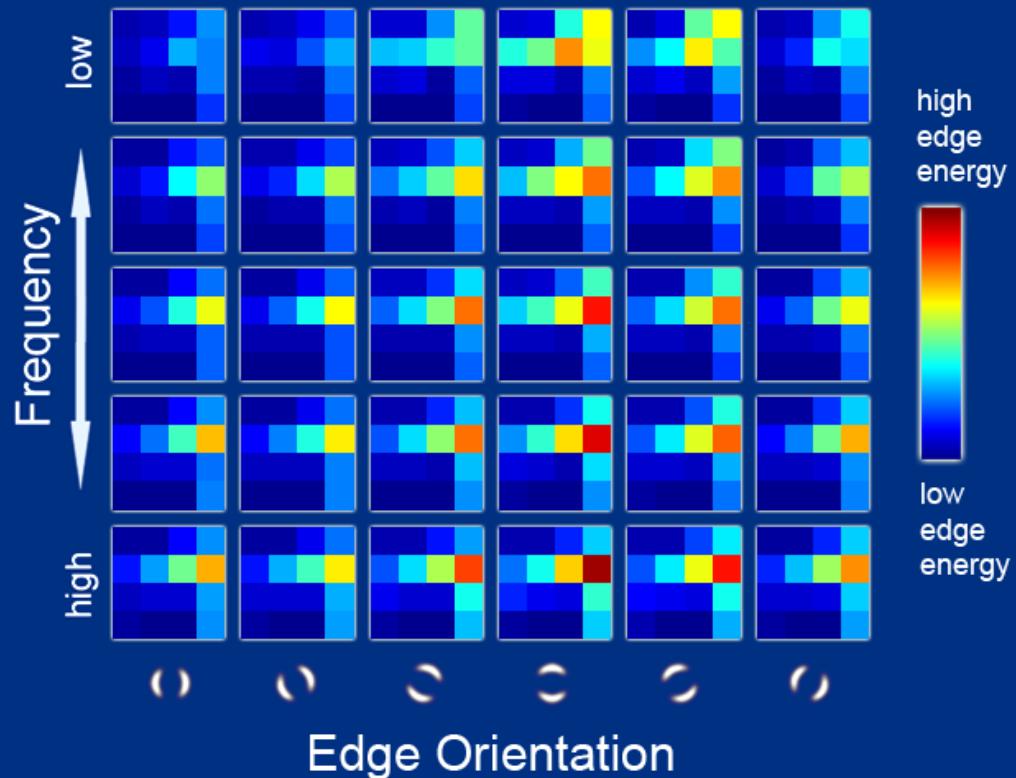
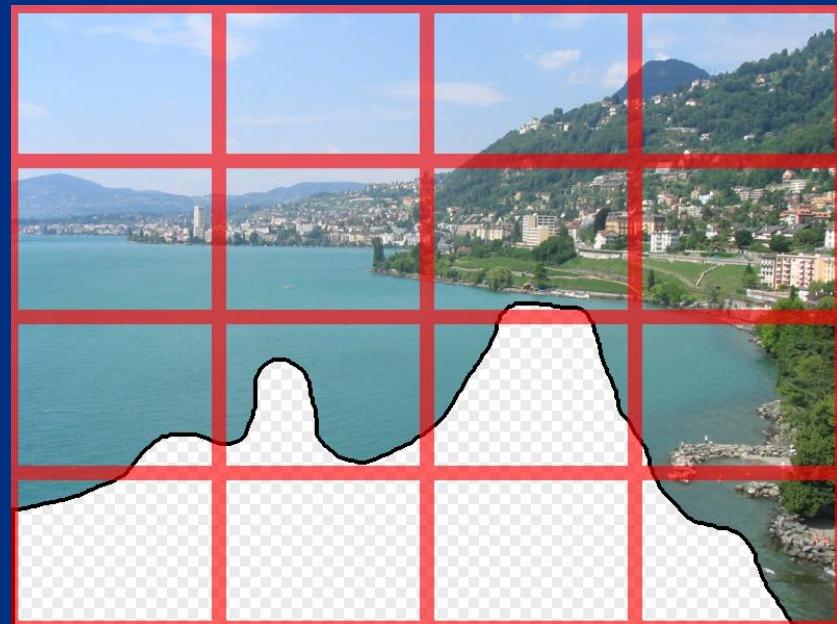
# Scene Matching



# Scene Descriptor

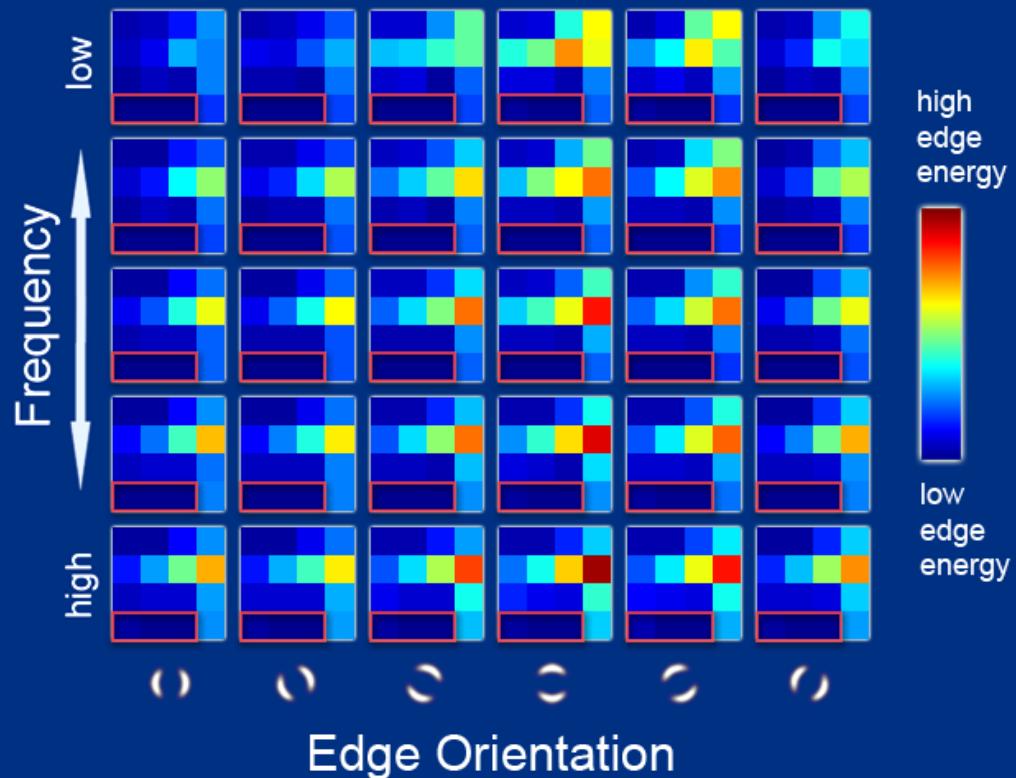
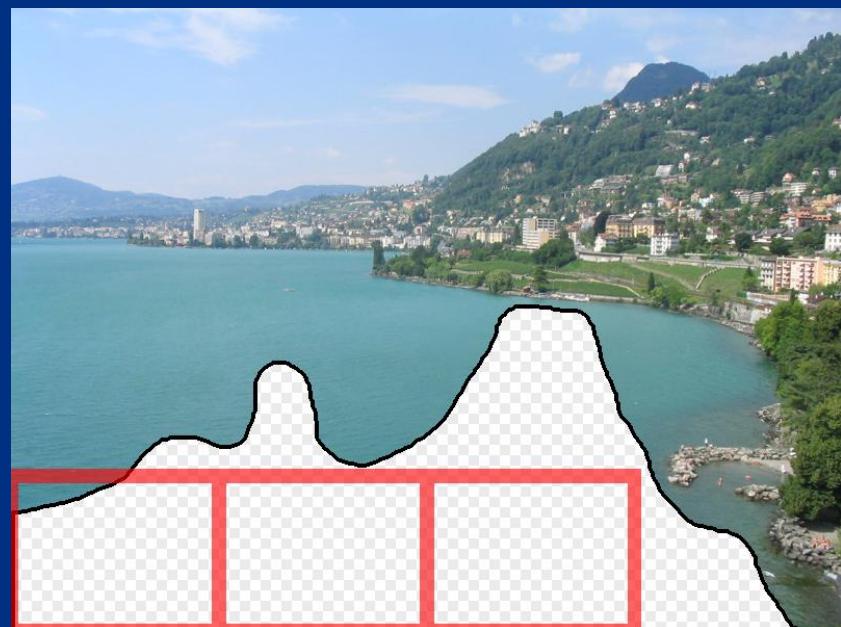


# Scene Descriptor



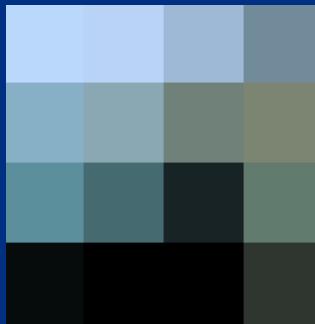
Gist scene descriptor  
(Oliva and Torralba 2001)

# Scene Descriptor

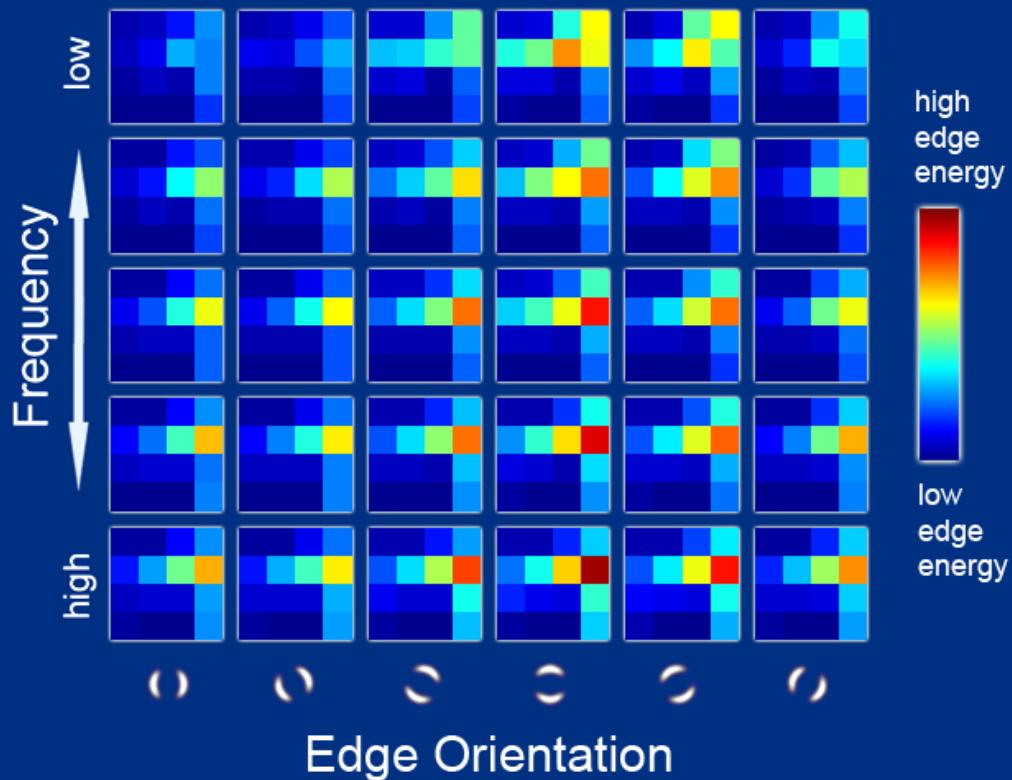


Gist scene descriptor  
(Oliva and Torralba 2001)

# Scene Descriptor

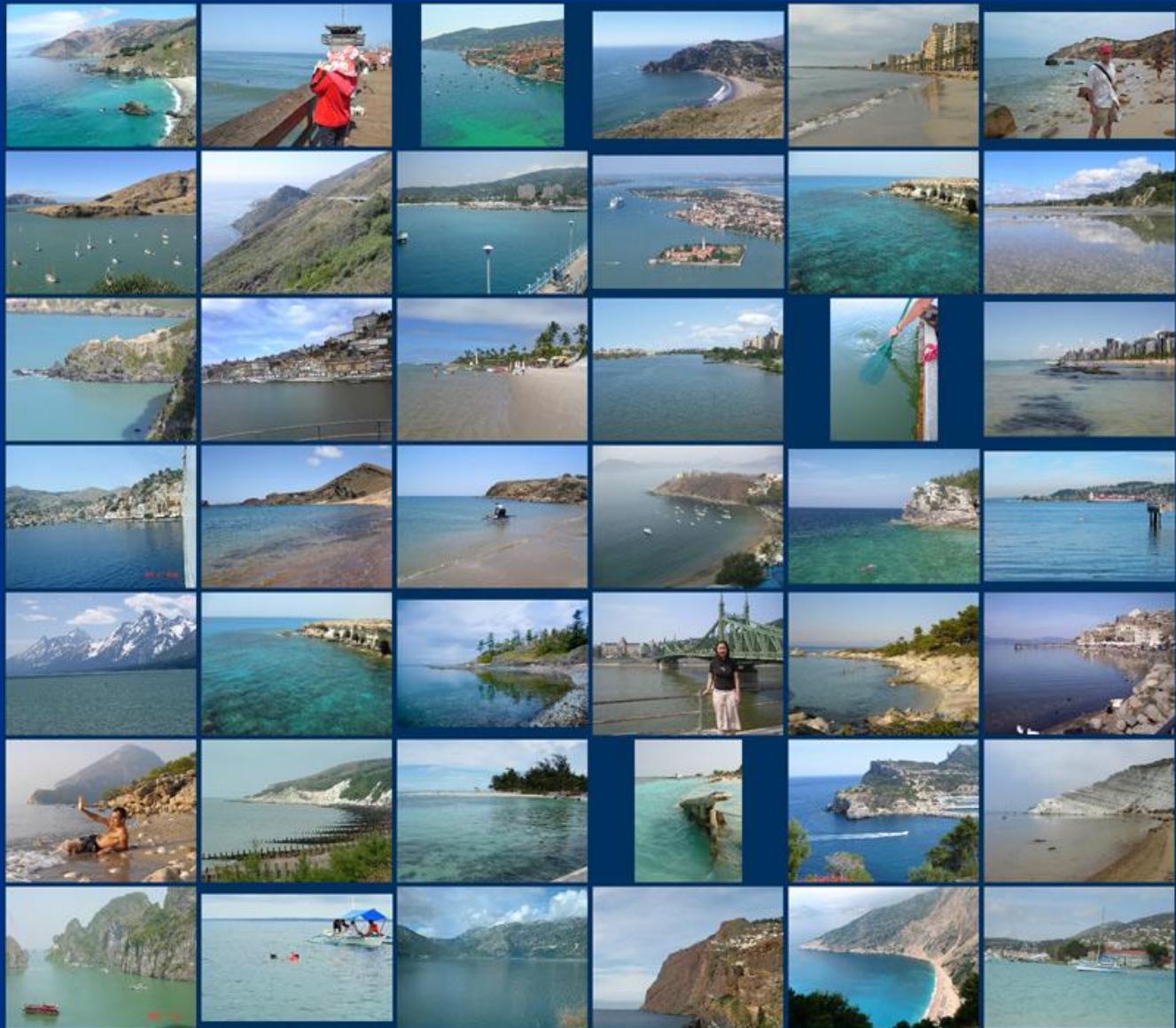
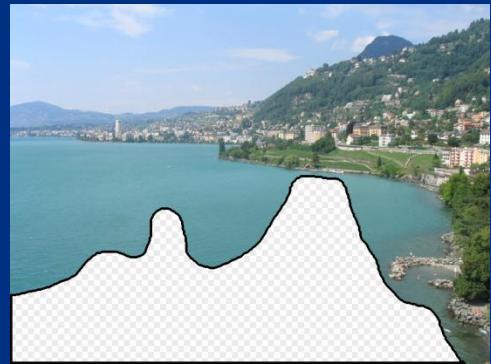


+



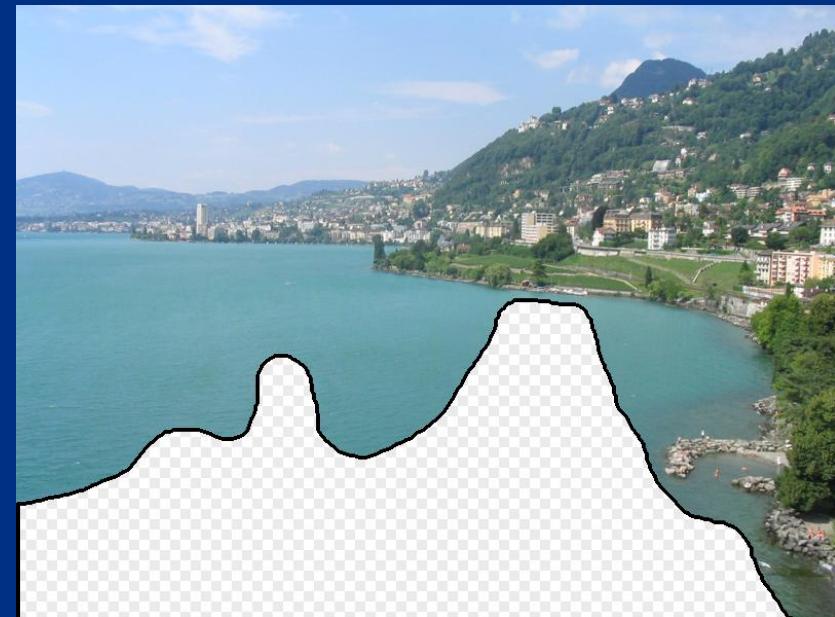
Gist scene descriptor  
(Oliva and Torralba 2001)





... 200 total

# Context Matching



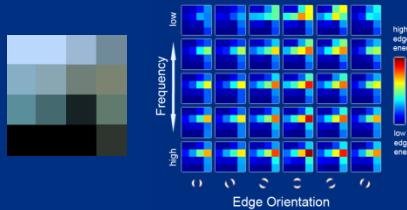


Graph cut + Poisson blending

Hays and Efros, SIGGRAPH 2007

# Result Ranking

We assign each of the 200 results a score which is the sum of:



The scene matching distance



The context matching distance  
(color + texture)



The graph cut cost

# Top 20 Results





Hays and Efros, SIGGRAPH 2007





Hays and Efros, SIGGRAPH 2007



Hays and Efros, SIGGRAPH 2007

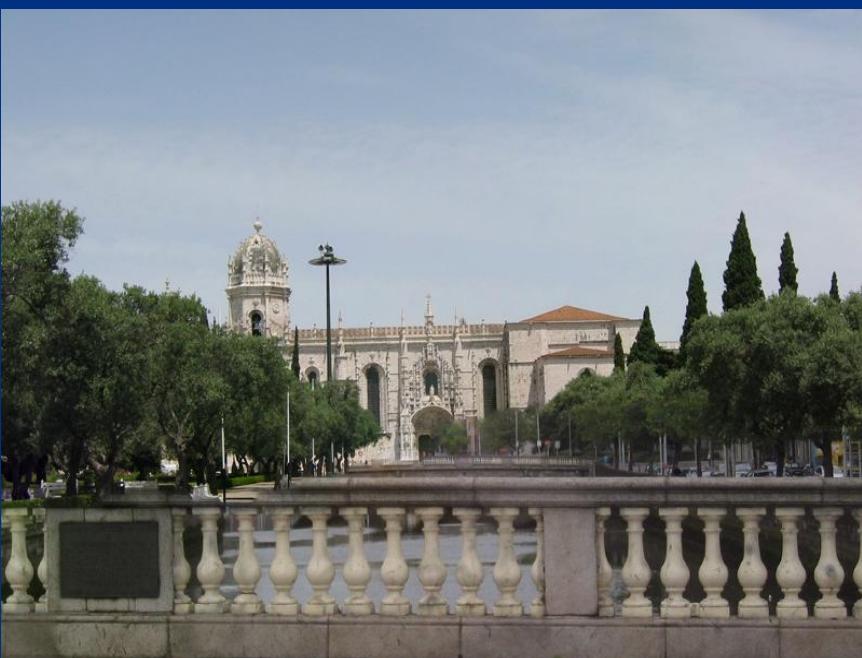


Hays and Efros, SIGGRAPH 2007





Hays and Efros, SIGGRAPH 2007





Hays and Efros, SIGGRAPH 2007



Hays and Efros, SIGGRAPH 2007



Hays and Efros, SIGGRAPH 2007



... 200 scene matches

Hays and Efros, SIGGRAPH 2007



... 200 scene matches

Hays and Efros, SIGGRAPH 2007

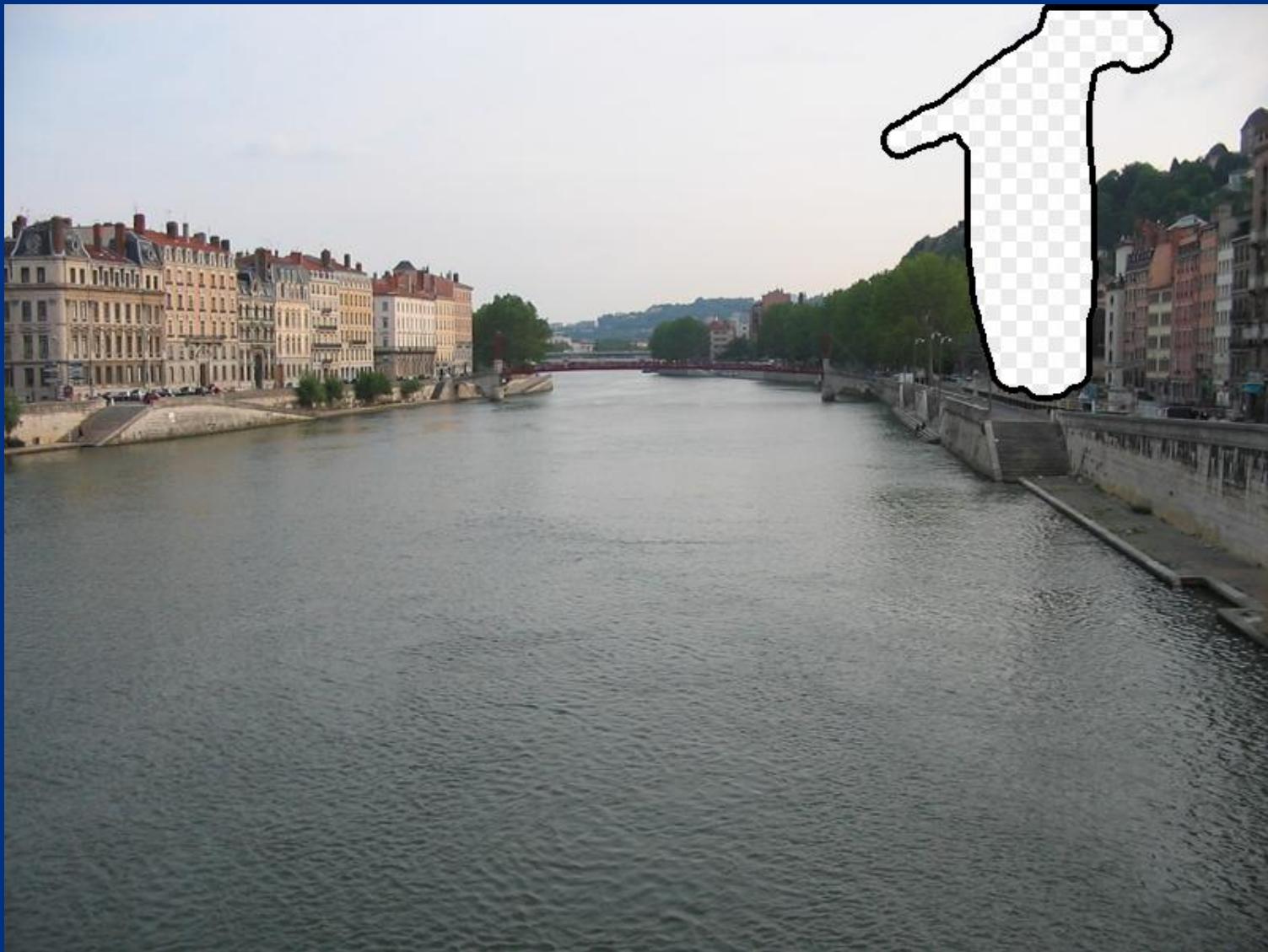


Hays and Efros, SIGGRAPH 2007

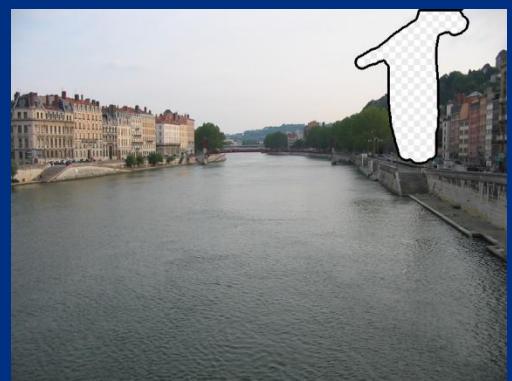


Hays and Efros, SIGGRAPH 2007

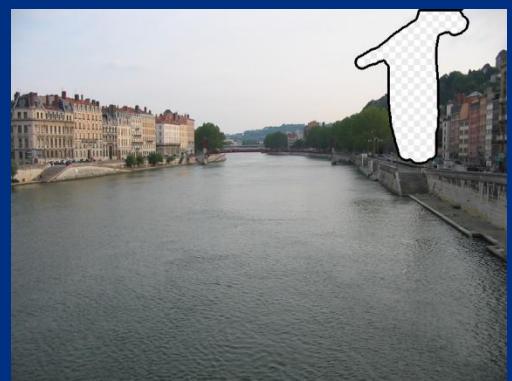




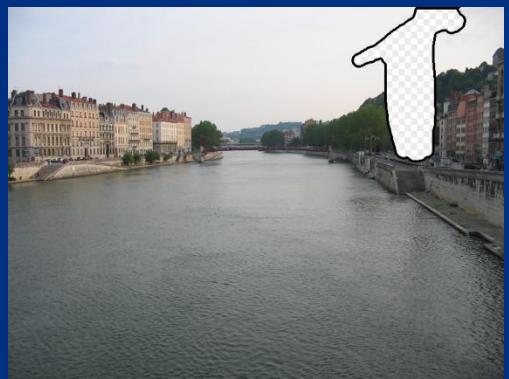




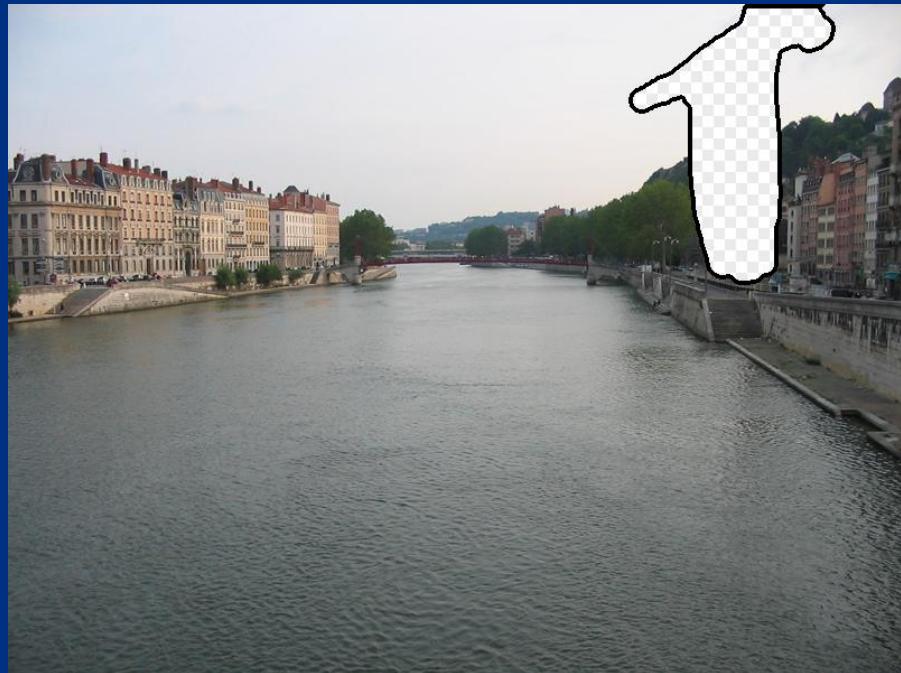
... 200 scene matches



... 200 scene matches



... 200 scene matches







Hays and Efros, SIGGRAPH 2007

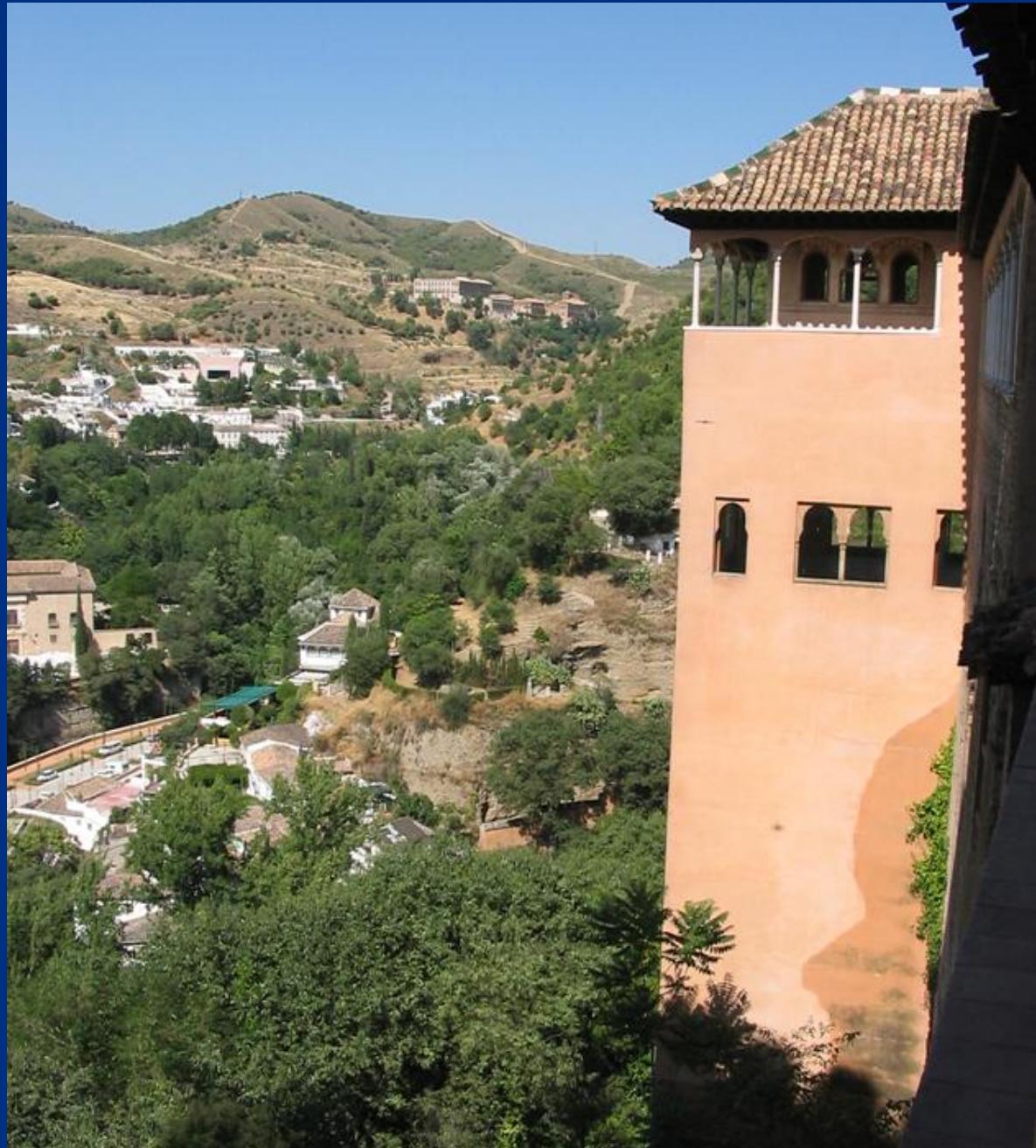


Hays and Efros, SIGGRAPH 2007

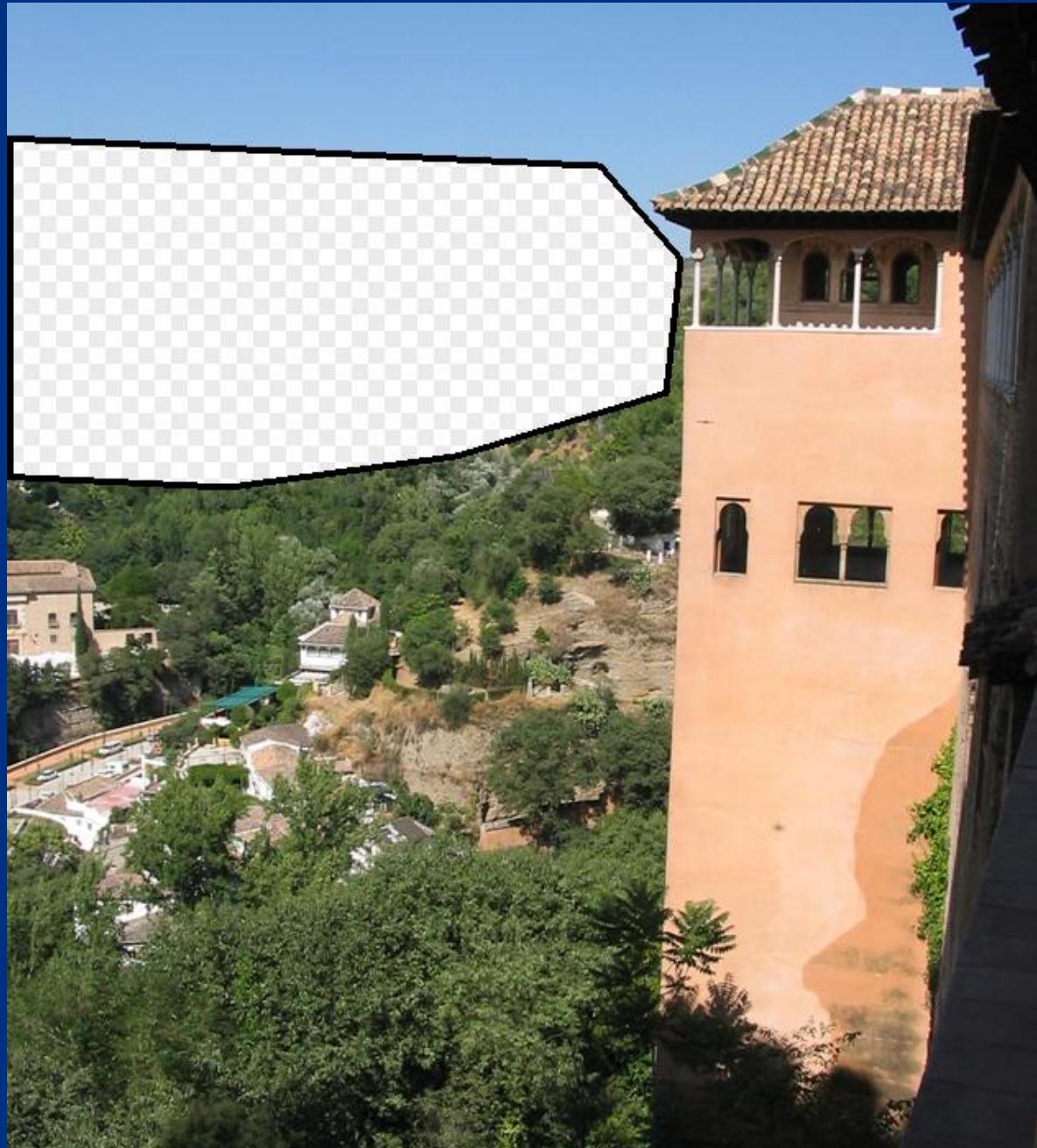




Hays and Efros, SIGGRAPH 2007



Hays and Efros, SIGGRAPH 2007



Hays and Efros, SIGGRAPH 2007



Hays and Efros, SIGGRAPH 2007



Hays and Efros, SIGGRAPH 2007

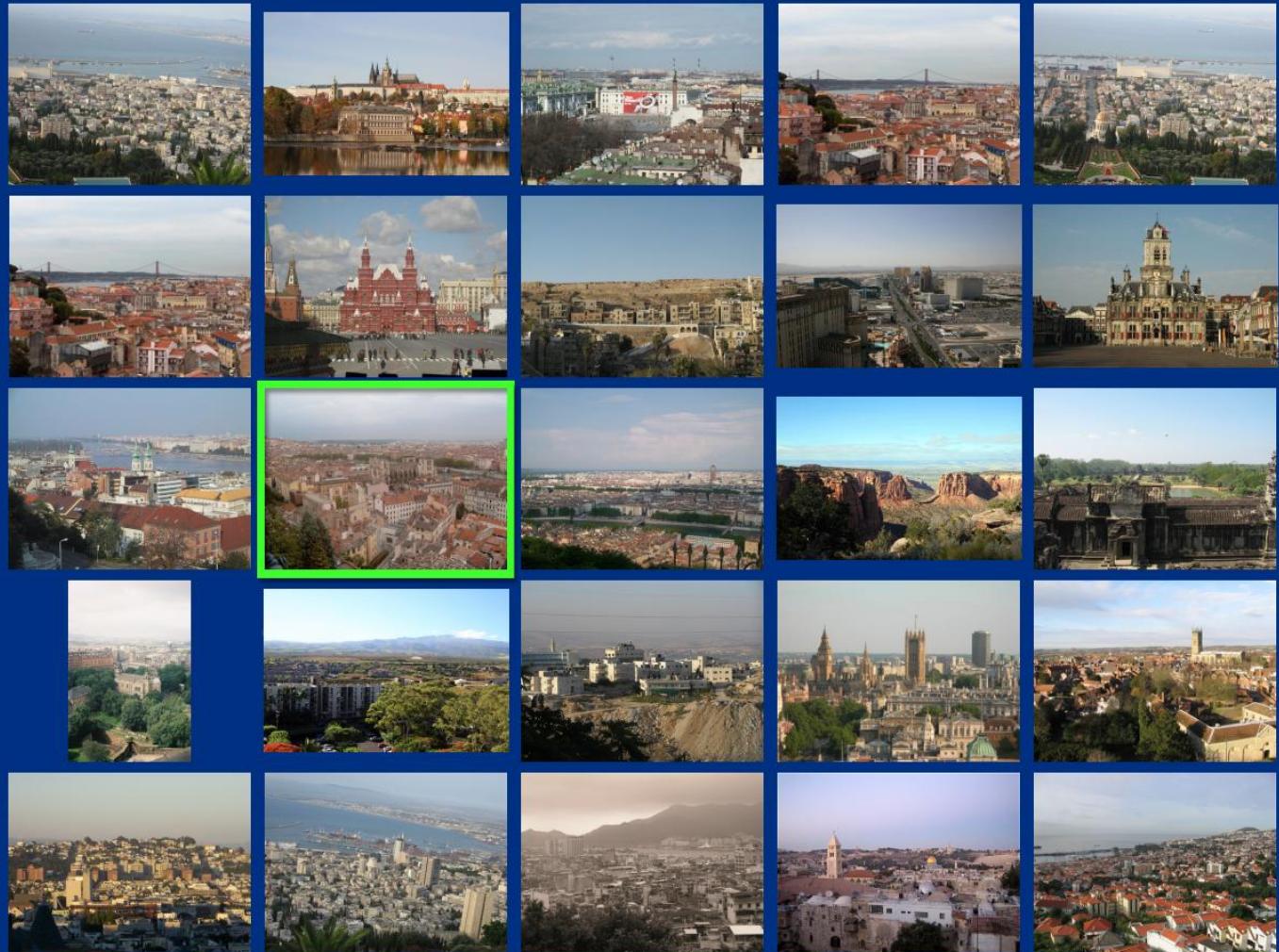




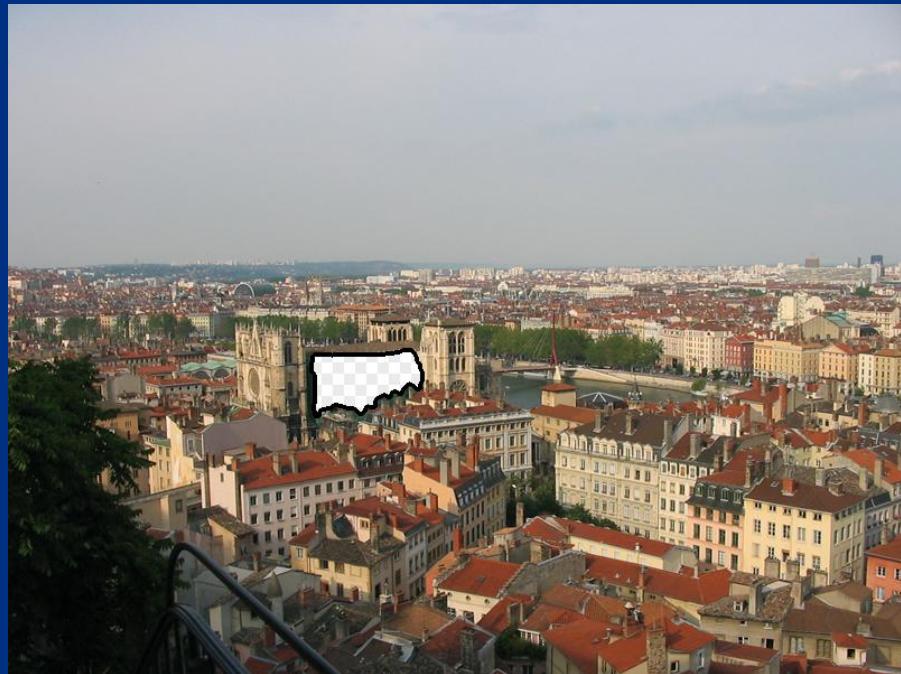




... 200 scene matches



... 200 scene matches





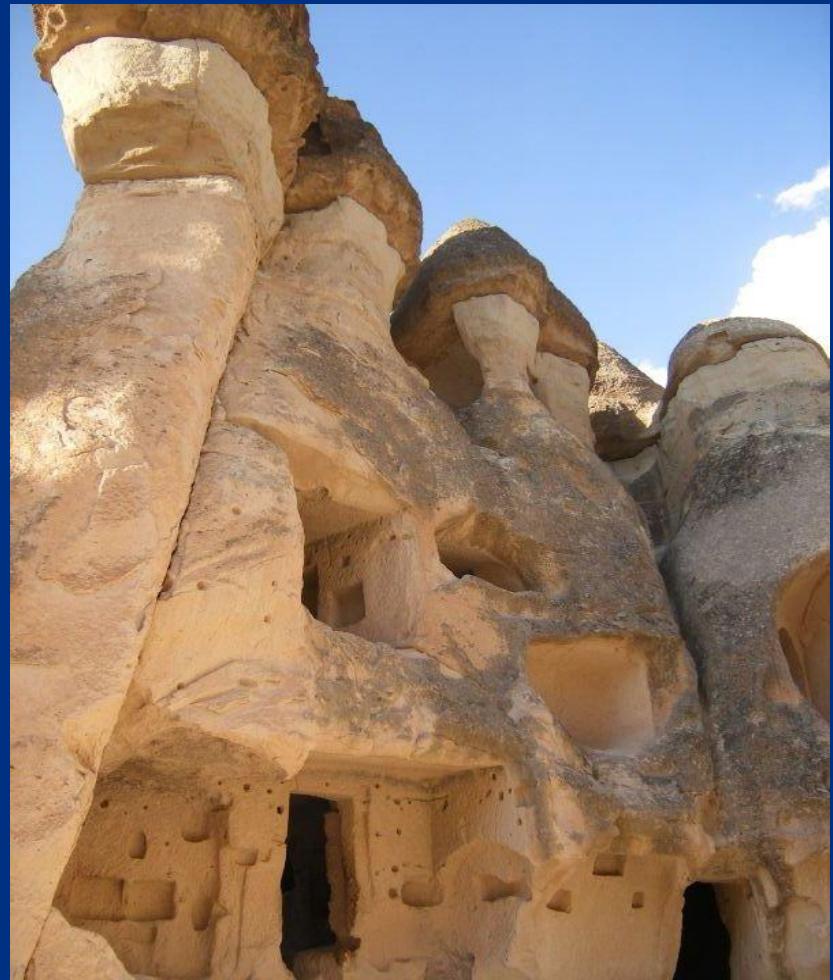
# Failures



# Failures



# Failures



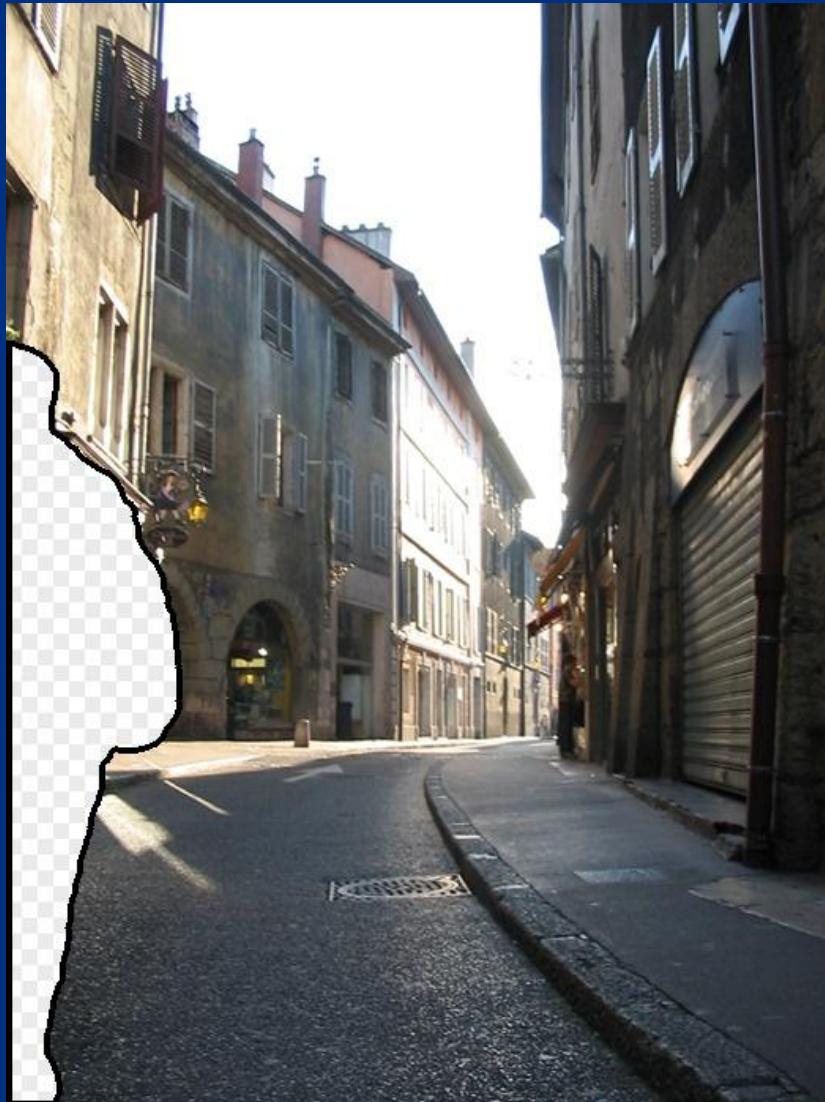
# Failures



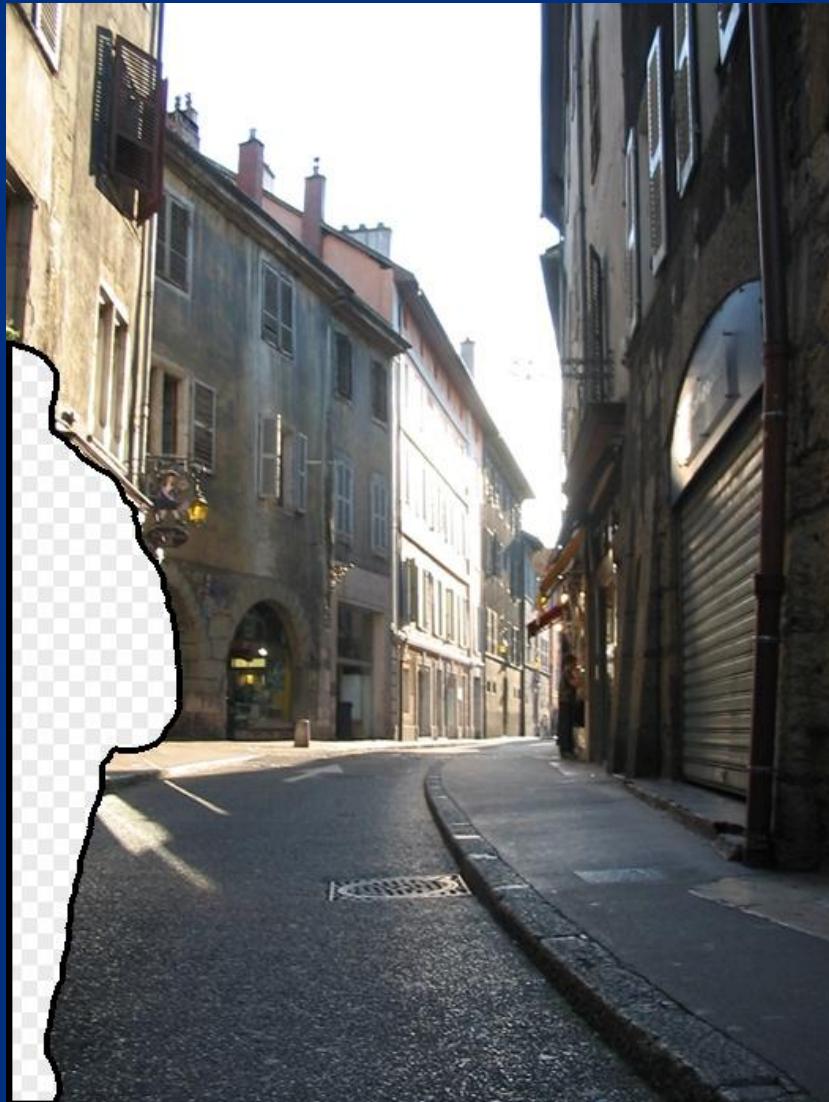
# Failures



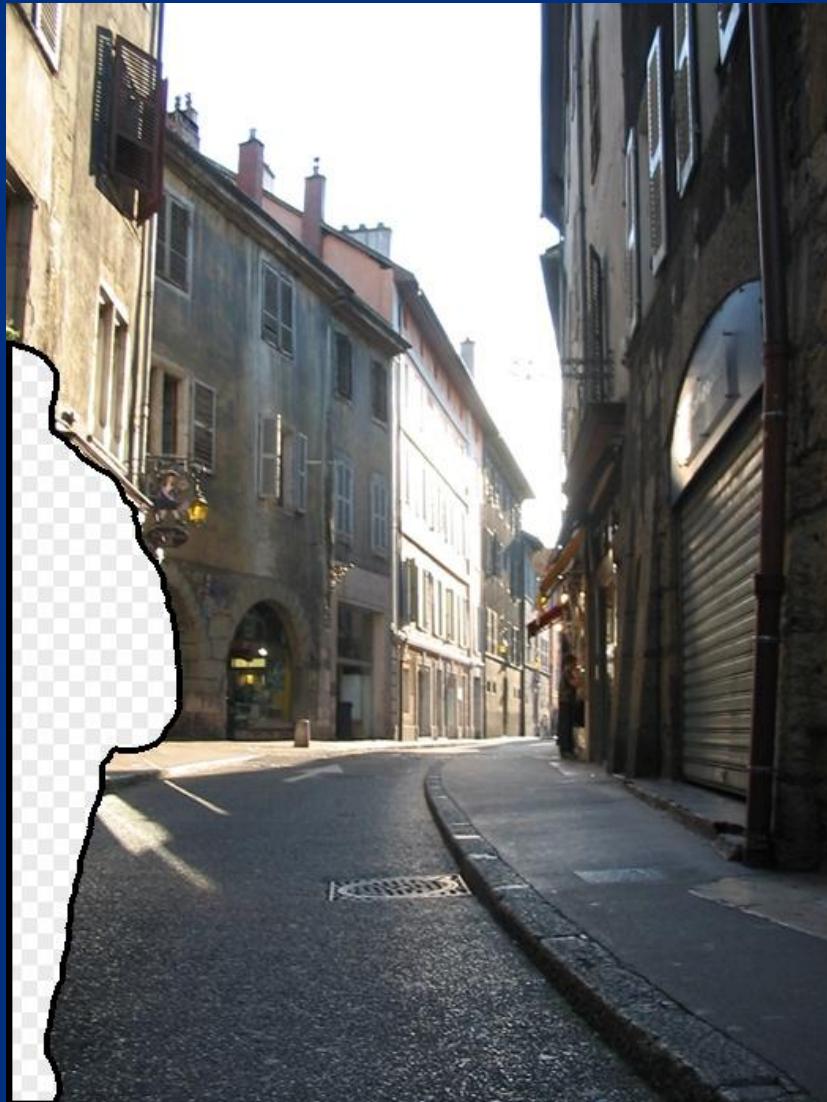
# Failures



# Failures



# Failures



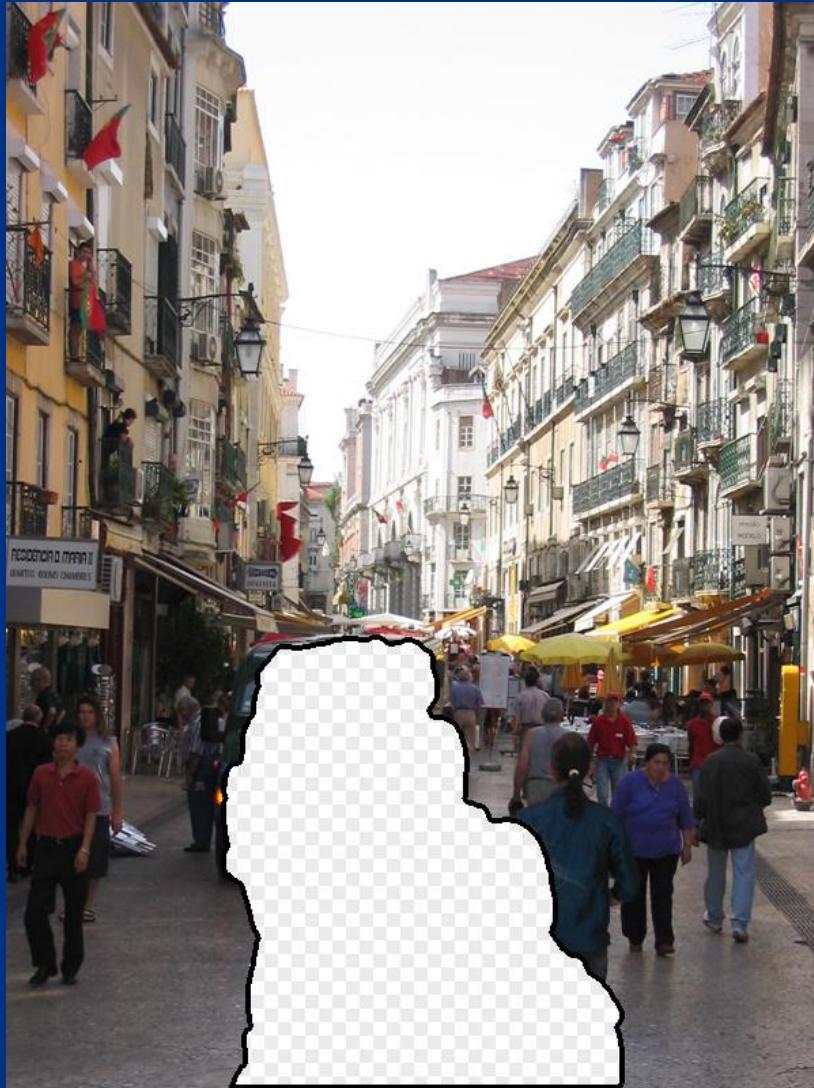
# Failures



# Failures



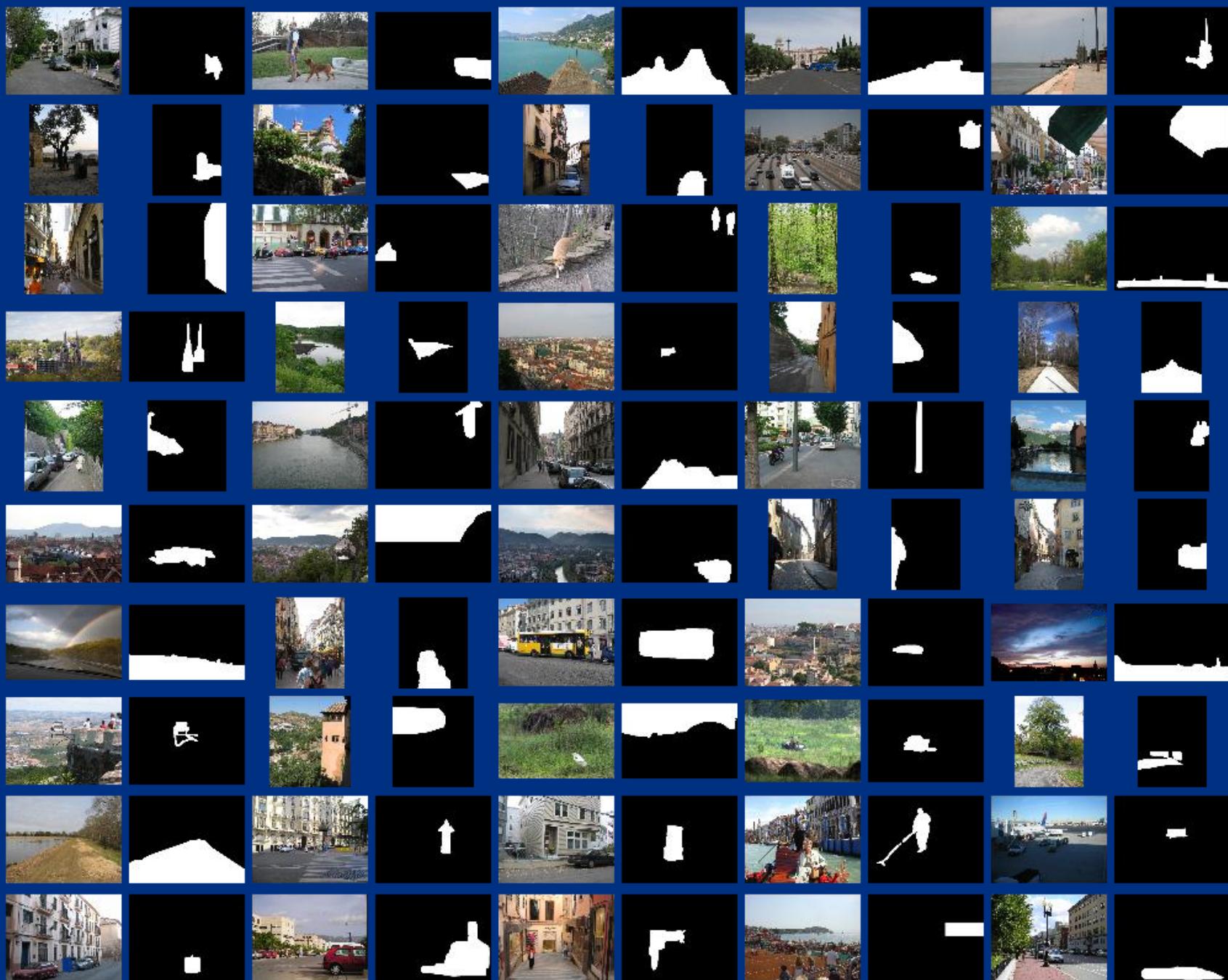
# Failures



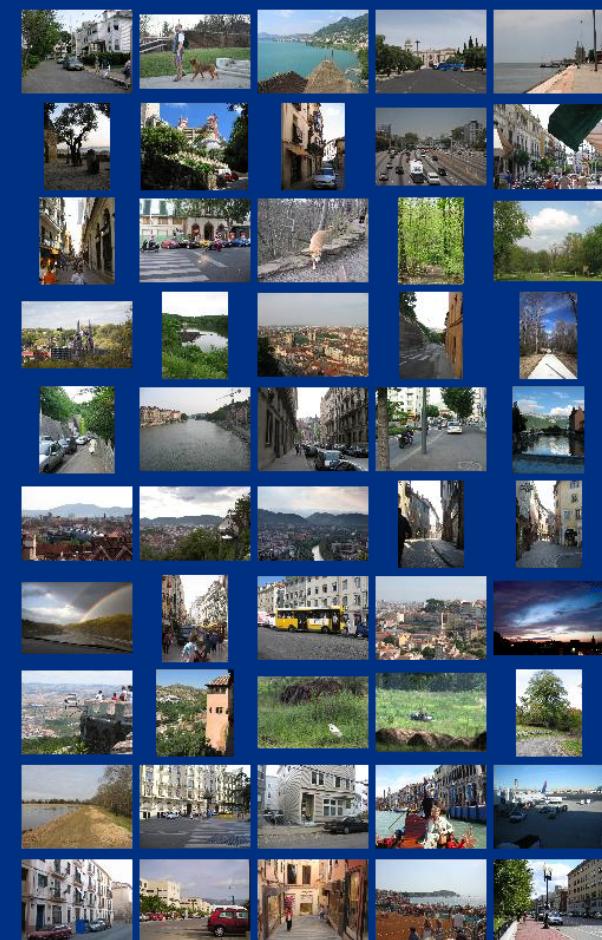
# Failures



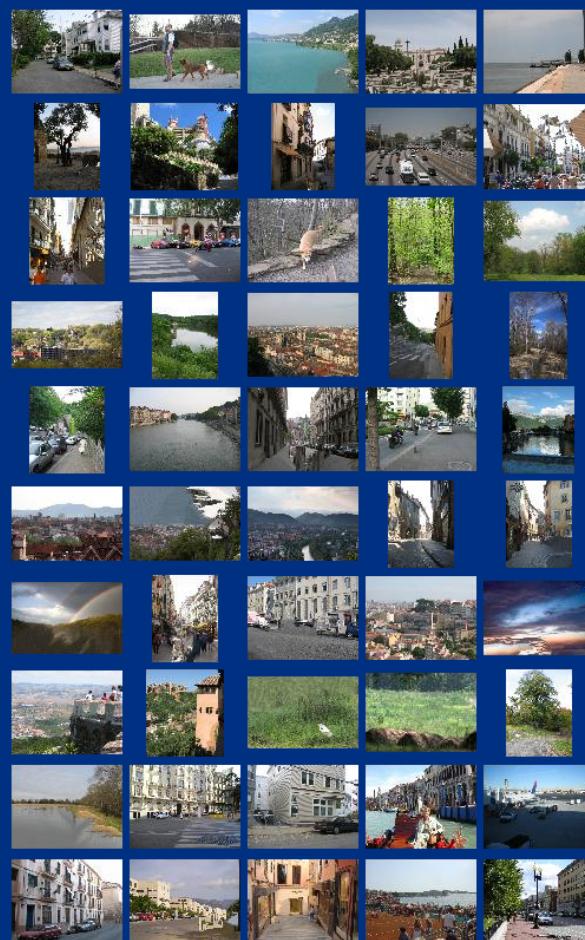
# Evaluation



Hays and Efros, SIGGRAPH 2007

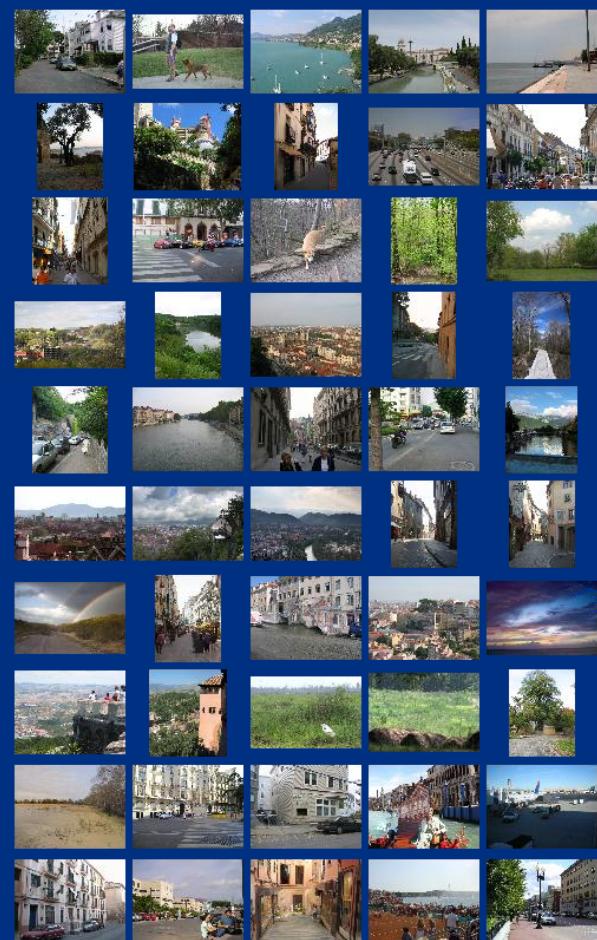


## Original Images



## Criminisi et al.

Single result



## Scene Completion

Each result  
selected from 20



# Original Images

Criminisi et al.

# Single result

# Scene Completion

## Each result selected from 20

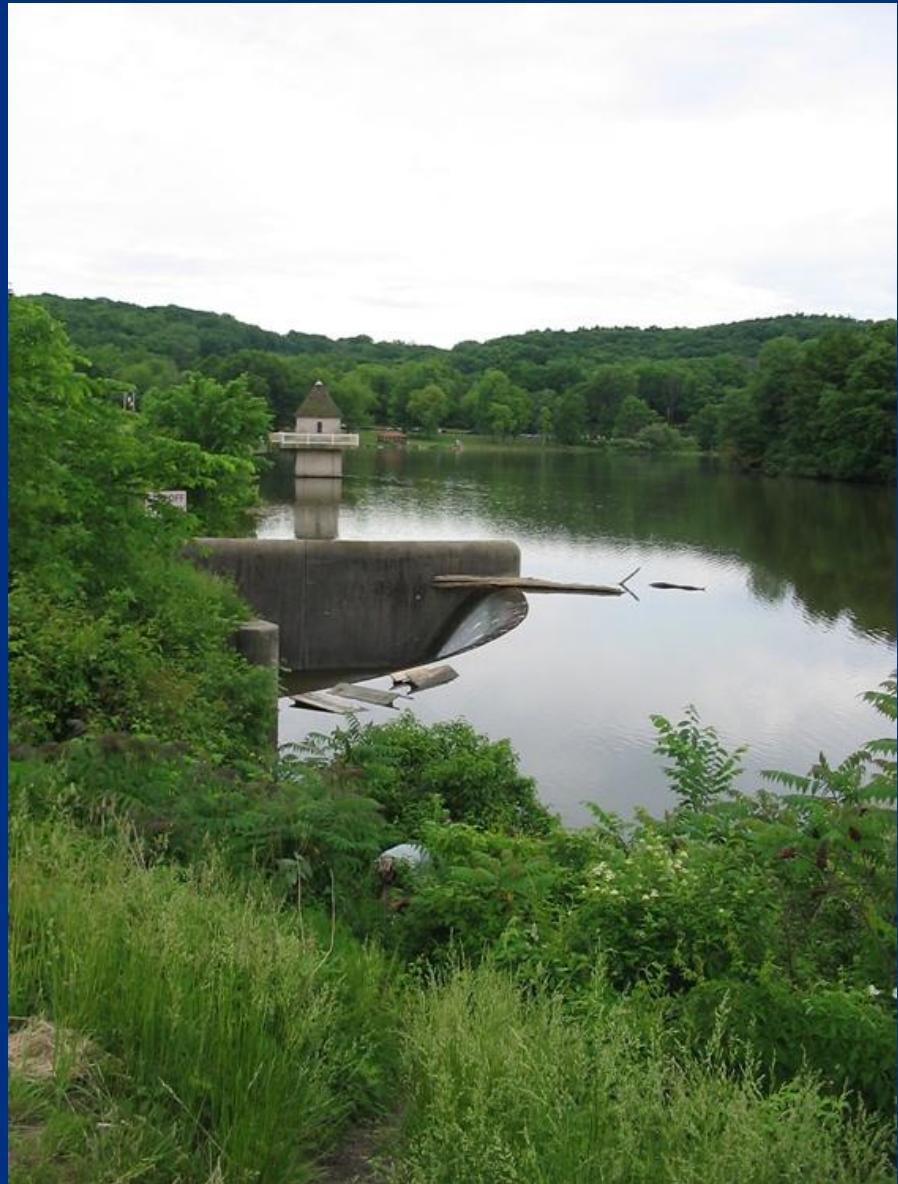


Real Image. This image  
has not been manipulated

or

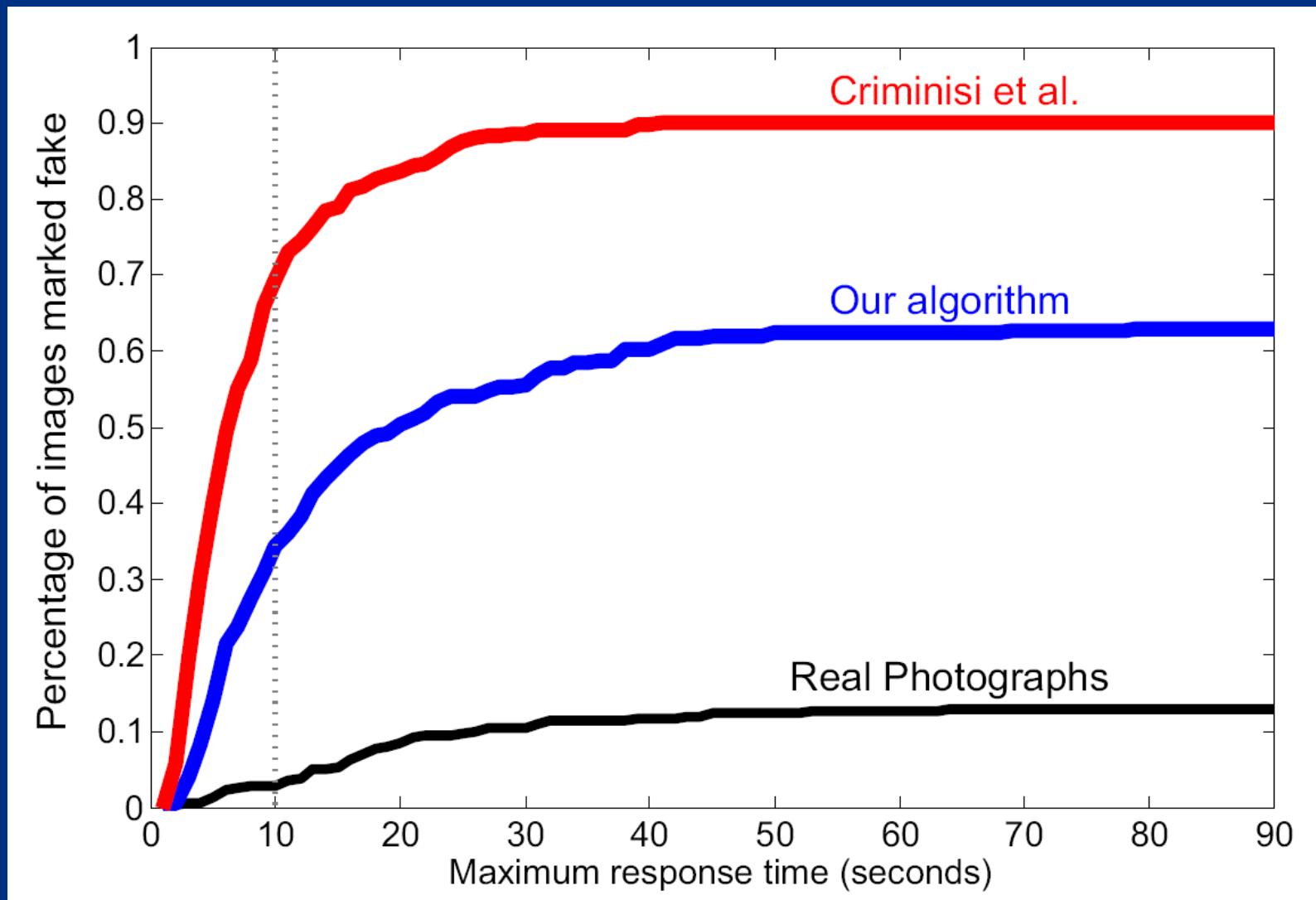
Fake Image. This image  
has been manipulated



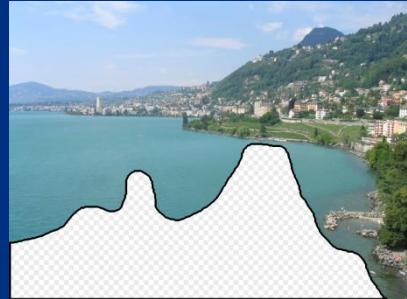


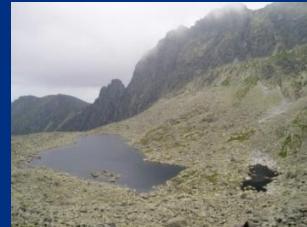
Hays and Efros, SIGGRAPH 2007

# User Study Results - 20 Participants

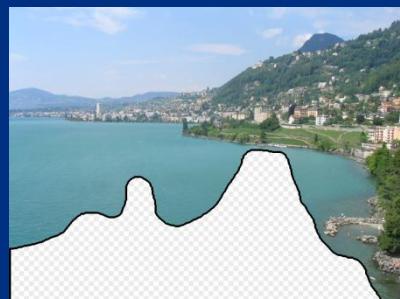
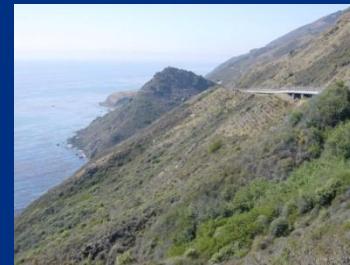


# Why does it work?

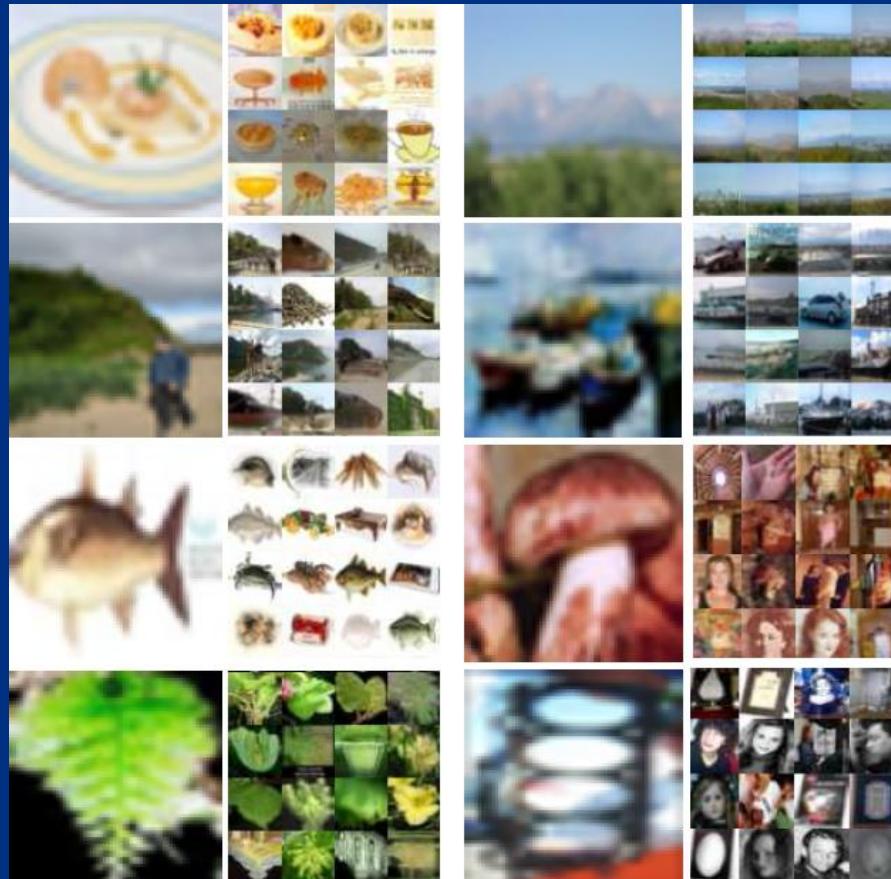




10 nearest neighbors from a collection of 20,000 images



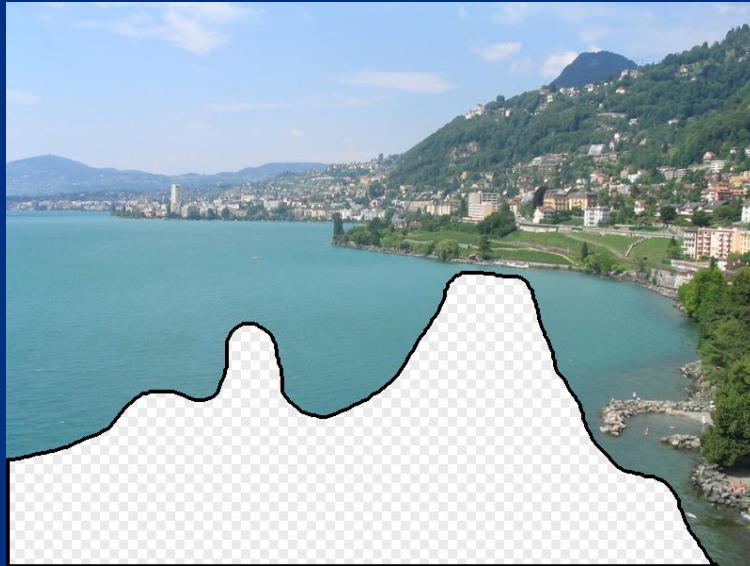
10 nearest neighbors from a collection of 2 million images



Database of 70 Million 32x32 images

Torralba, Fergus, and Freeman. Tiny Images.  
MIT-CSAIL-TR-2007-024. 2007.

# The Small Picture



Pixels



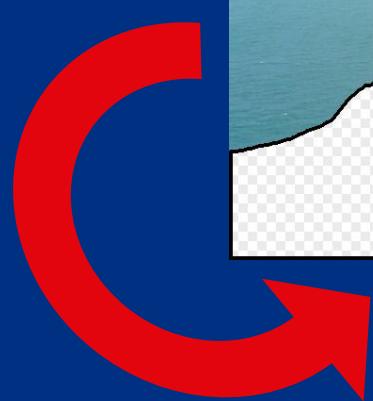
Image Collection

Pixels + Semantics

# Expert-supplied Semantics



# Hybrid Solution?



Pixels

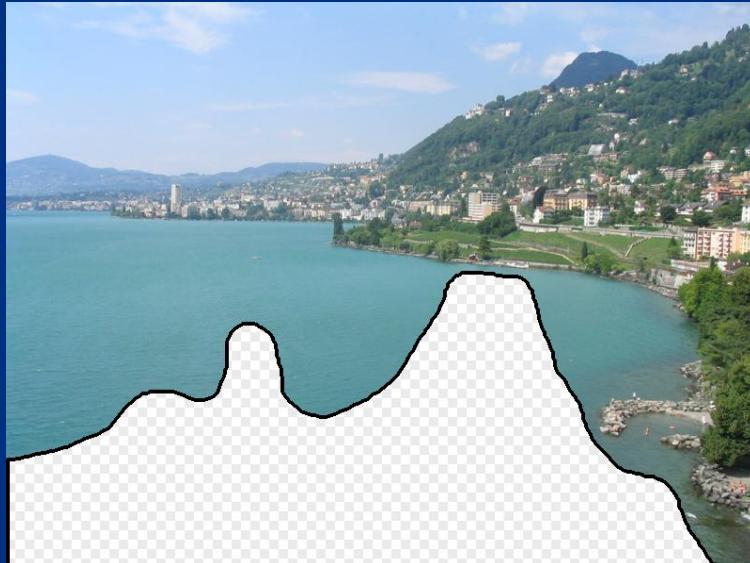


Image Collection

Semantics

# The Big Picture



Sky, Water, Hills, Beach,  
Sunny, mid-day

Brute-force Image Understanding

