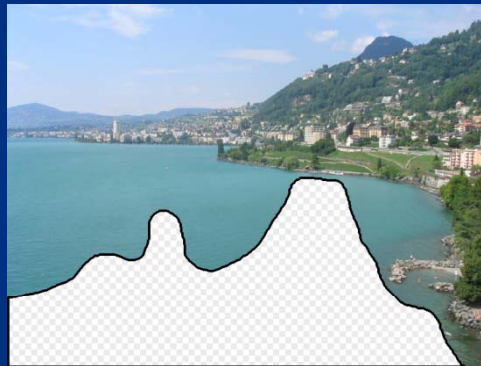


# Scene Completion Using Millions of Photographs



SIGGRAPH2007



James Hays and Alexei A. Efros  
Carnegie Mellon University



Modified slides from authors' slides



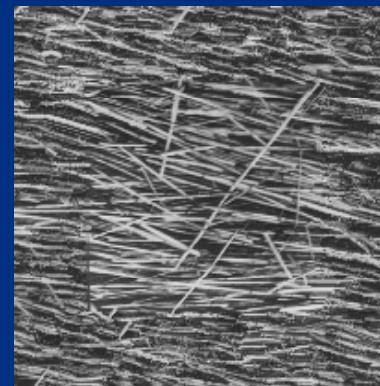
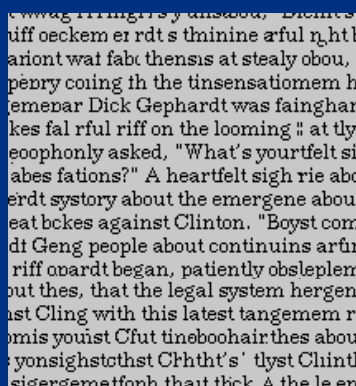
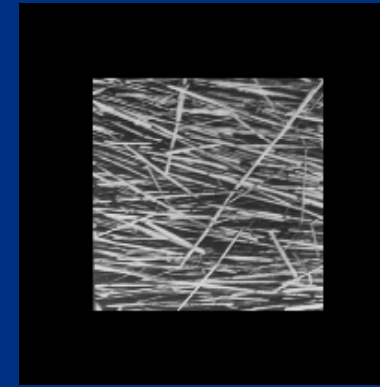
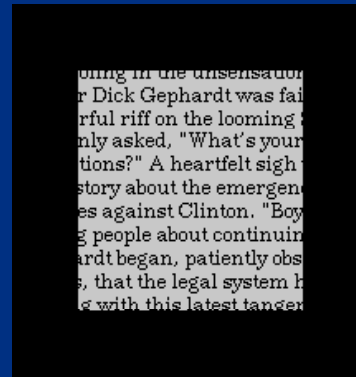
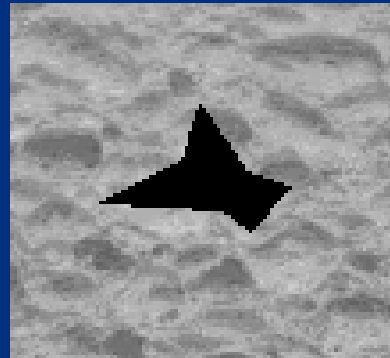




Bertalmio, Sapiro, Caselles, and Ballester.  
Image Inpainting. SIGGRAPH 2000.



Diffusion Result



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



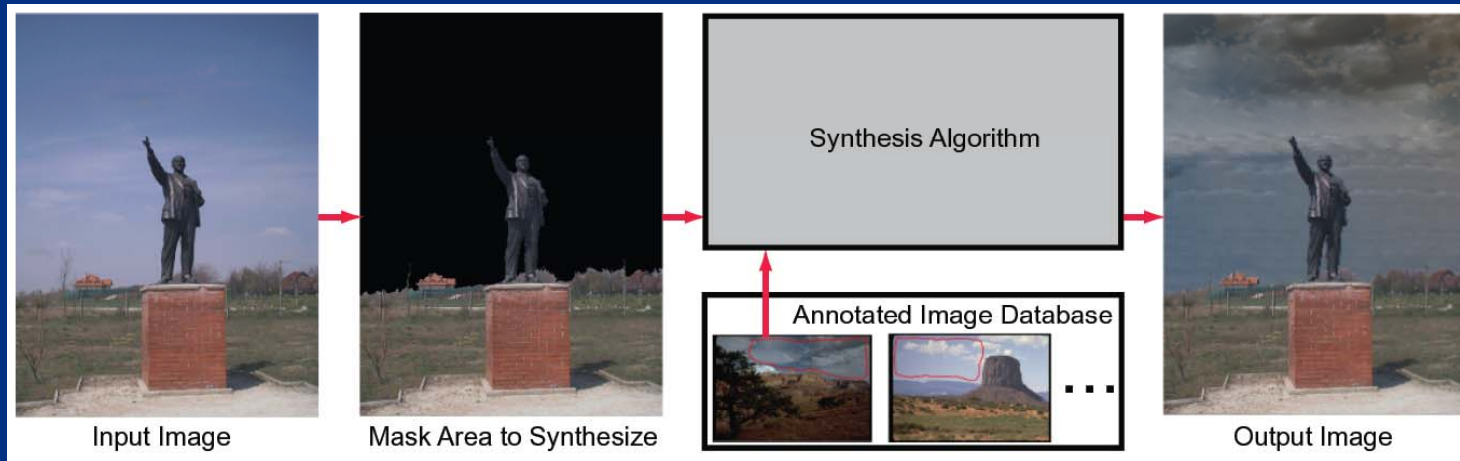
Efros and Leung result



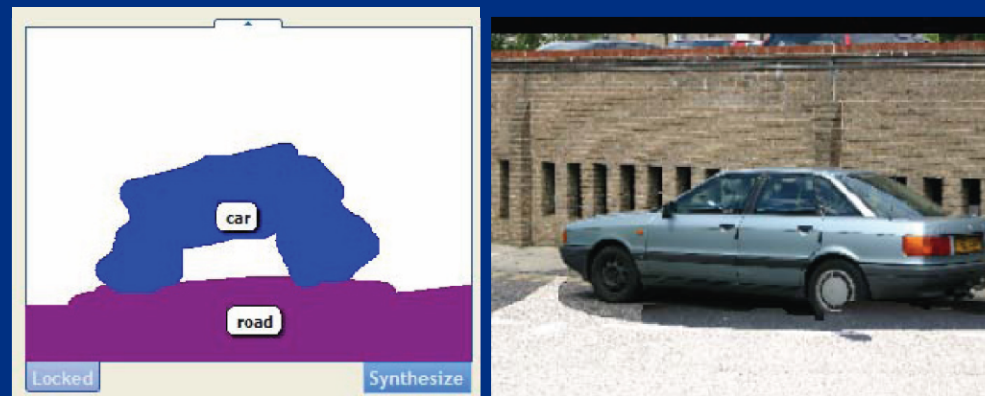




Road



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.



# Scene Matching for Image Completion





alley  
Strict SafeSearch is on

Search Images

Search the Web

[Advanced Image Search](#)  
[Preferences](#)

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



Looking west past Printers **Alley**.  
679 x 450 - 469k - jpg  
[franklin.thefuntimesguide.com](http://franklin.thefuntimesguide.com)



More Bubble Gum **Alley** photos can be ...  
679 x 450 - 464k - jpg  
[franklin.thefuntimesguide.com](http://franklin.thefuntimesguide.com)



Gasoline **Alley** gang  
692 x 430 - 177k - jpg  
[newcritics.com](http://newcritics.com)



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)



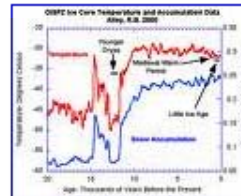
Grace Court **Alley**  
732 x 549 - 98k - jpg  
[www.bridgeandtunnelclub.com](http://www.bridgeandtunnelclub.com)



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)



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



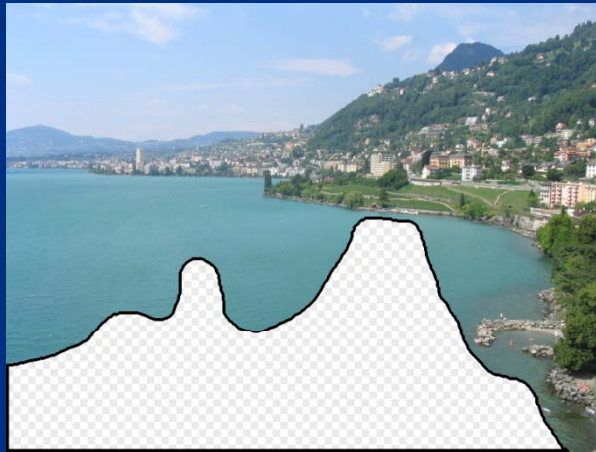
Richard B. **Alley**  
450 x 361 - 29k - gif  
[www.ncdc.noaa.gov](http://www.ncdc.noaa.gov)



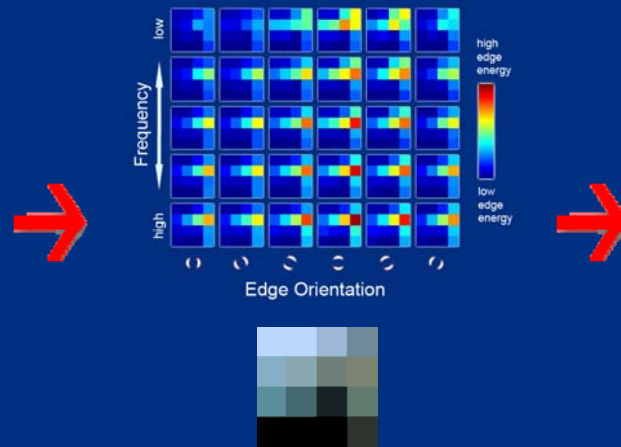


## Scene Completion Result

# The Algorithm



Input image



Scene Descriptor

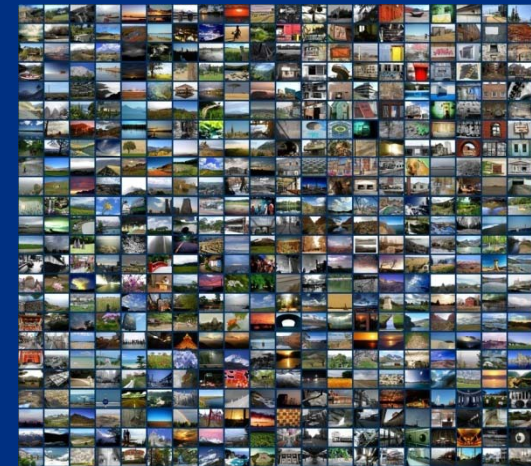


Image Collection



20 completions



Context matching  
+ blending



200 matches

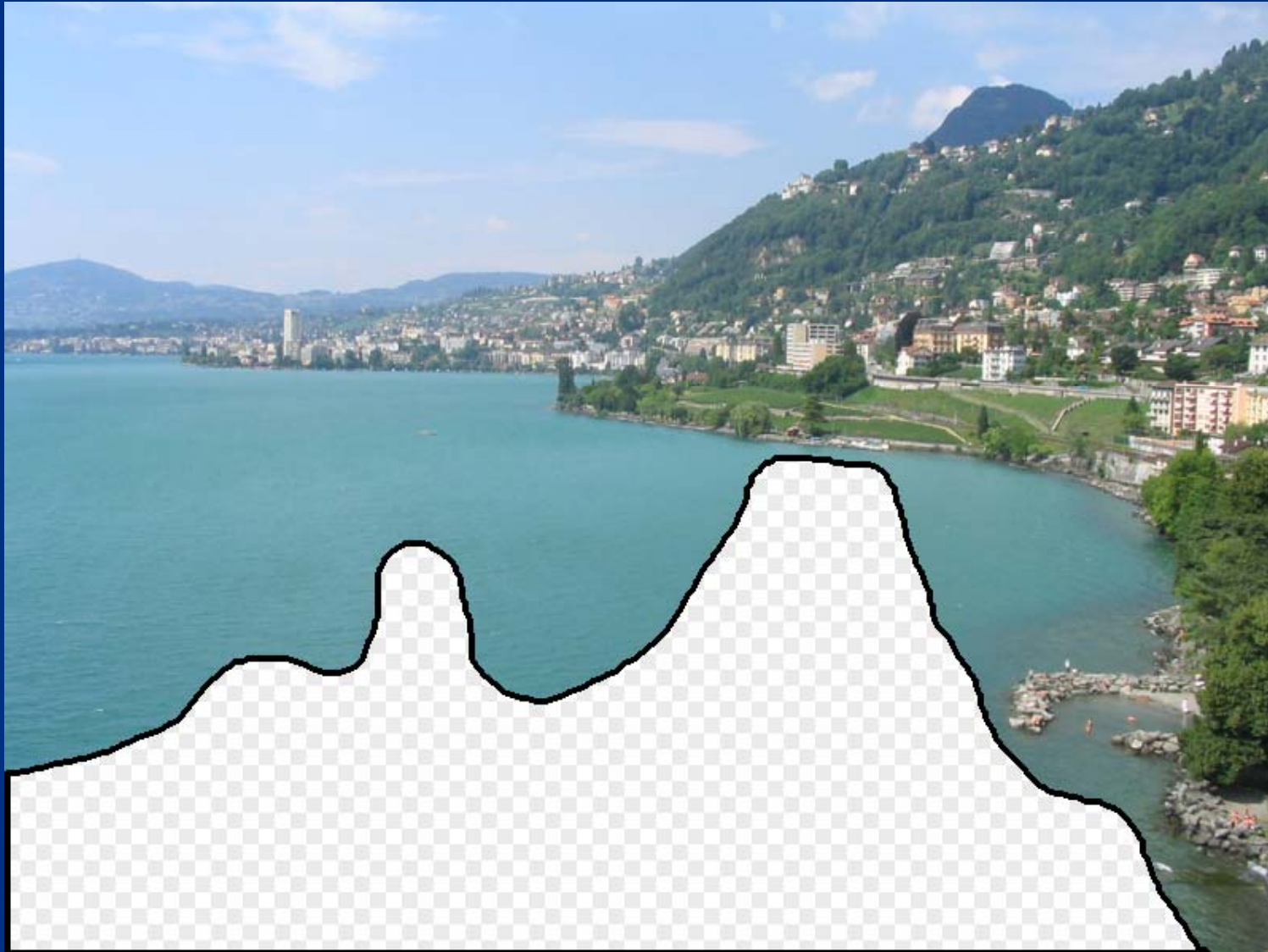


# Data

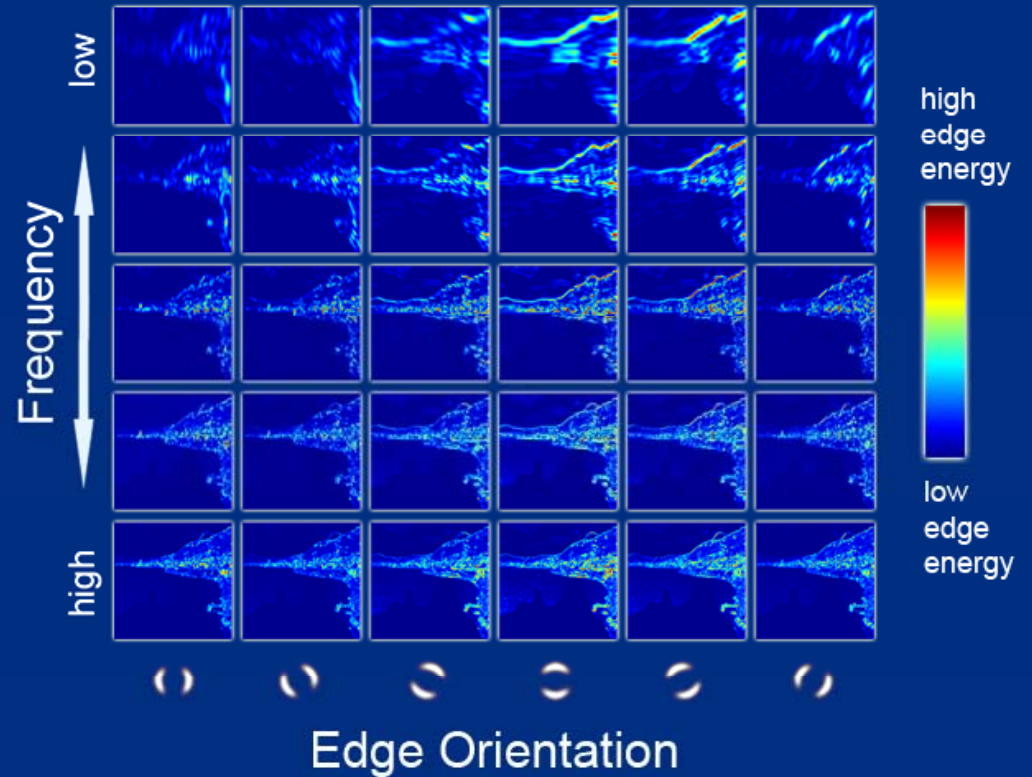
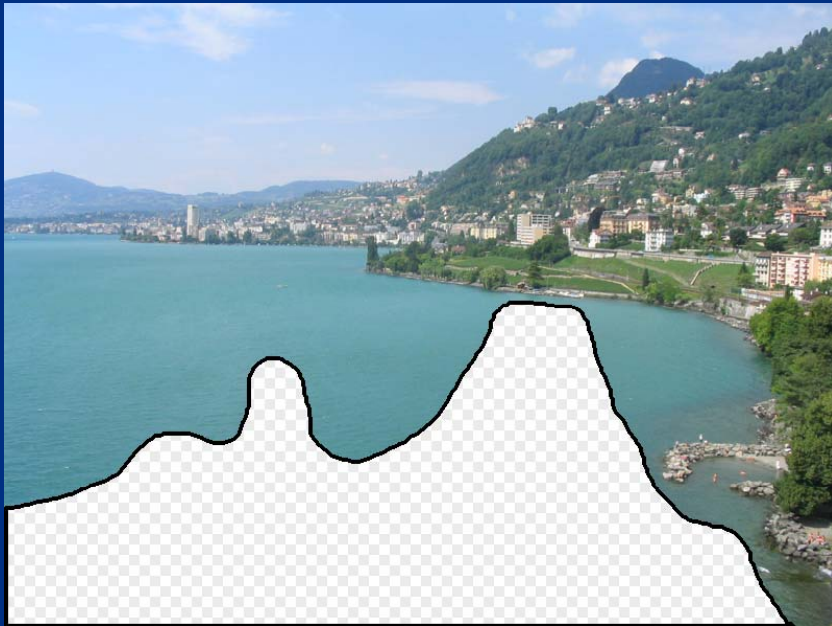
We downloaded 2.3 Million unique images from Flickr groups and keyword searches.



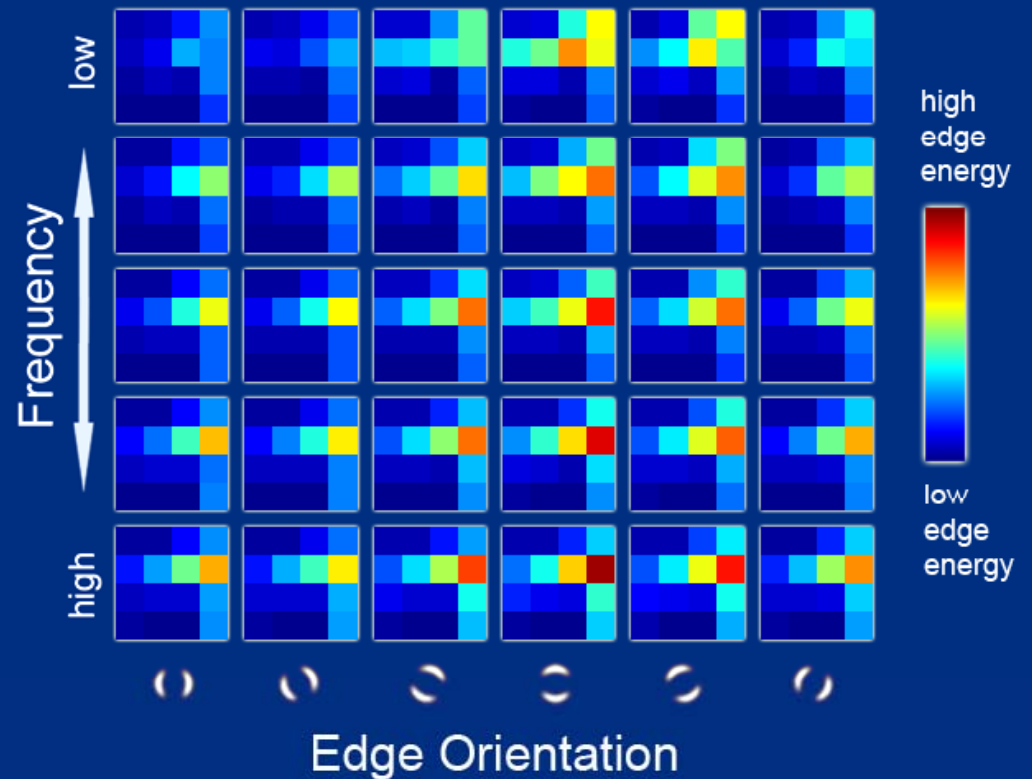
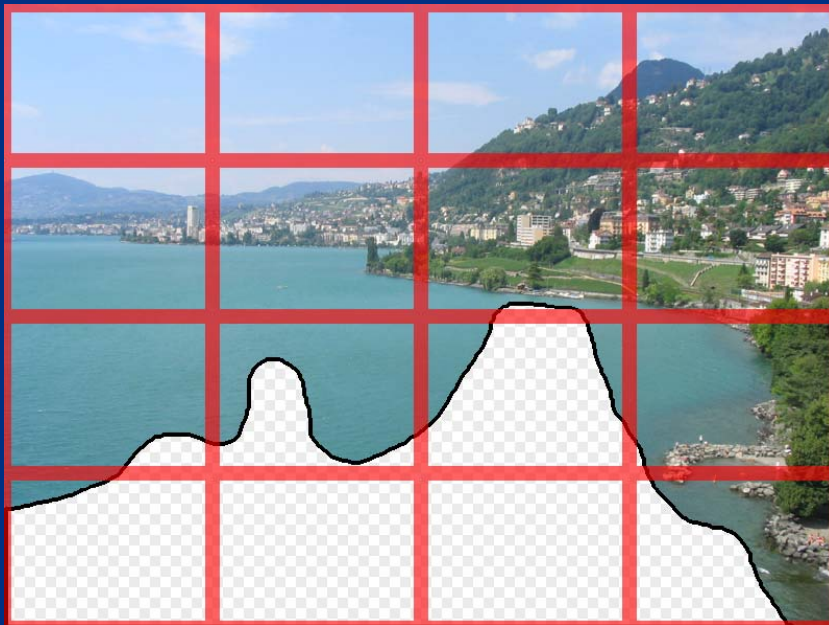
# Scene Matching



# Scene Descriptor

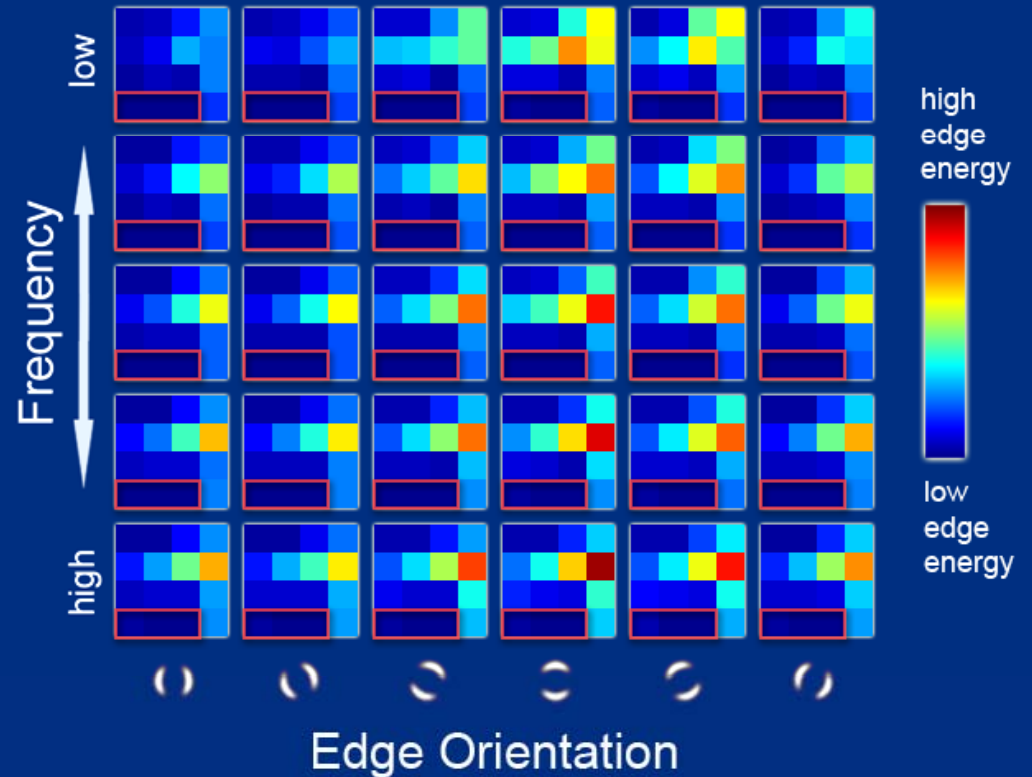
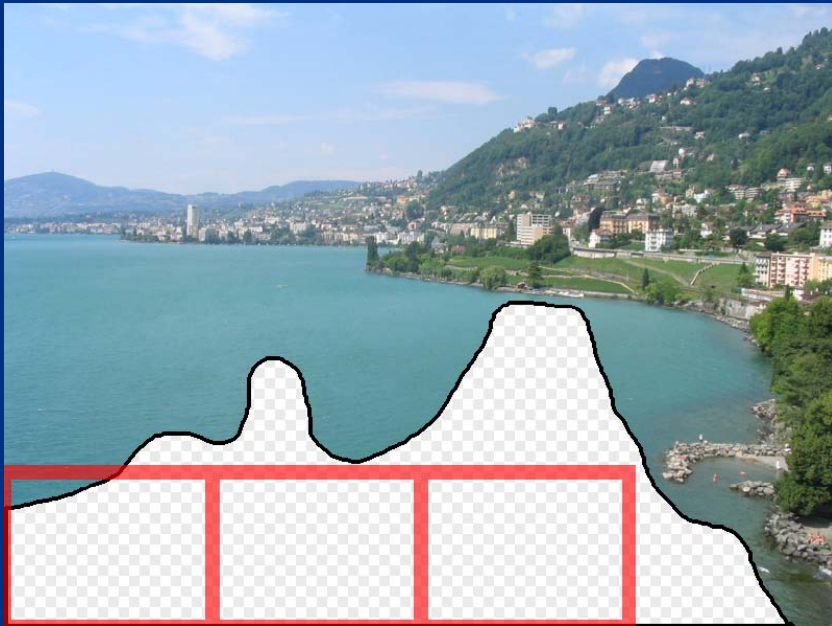


# Scene Descriptor



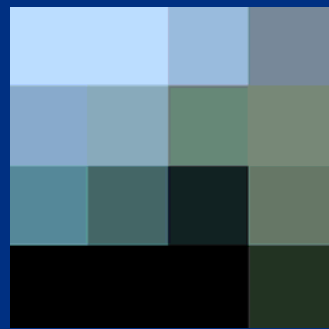
Gist scene descriptor  
(Oliva and Torralba 2001)

# Scene Descriptor

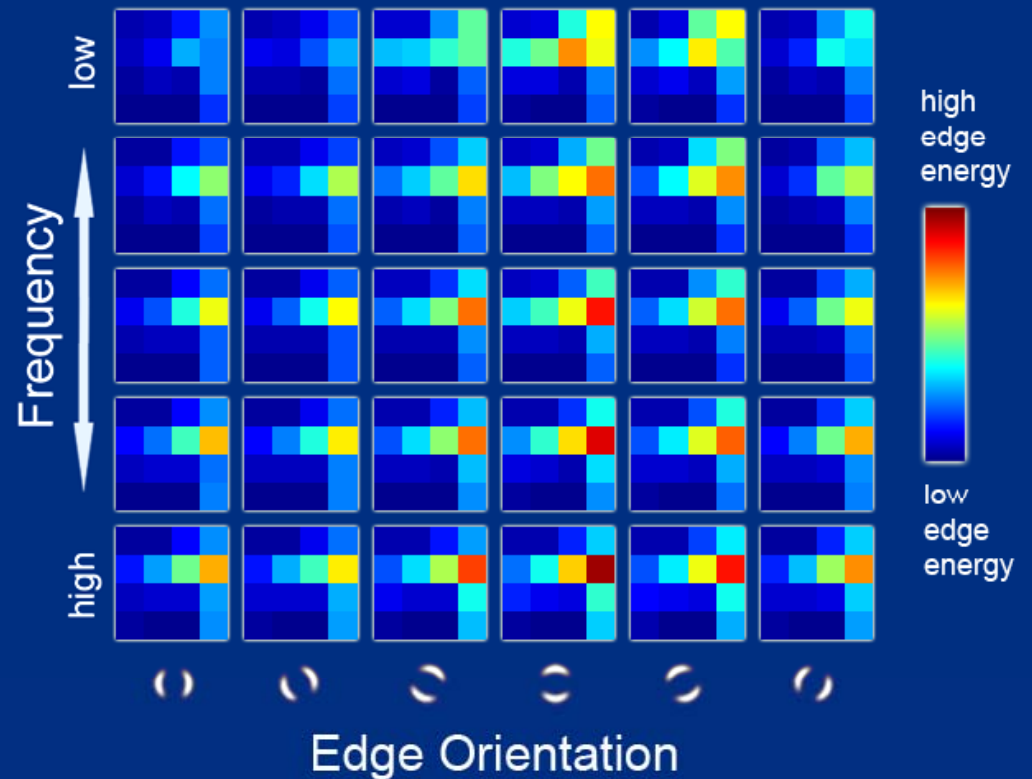


Gist scene descriptor  
(Oliva and Torralba 2001)

# Scene Descriptor

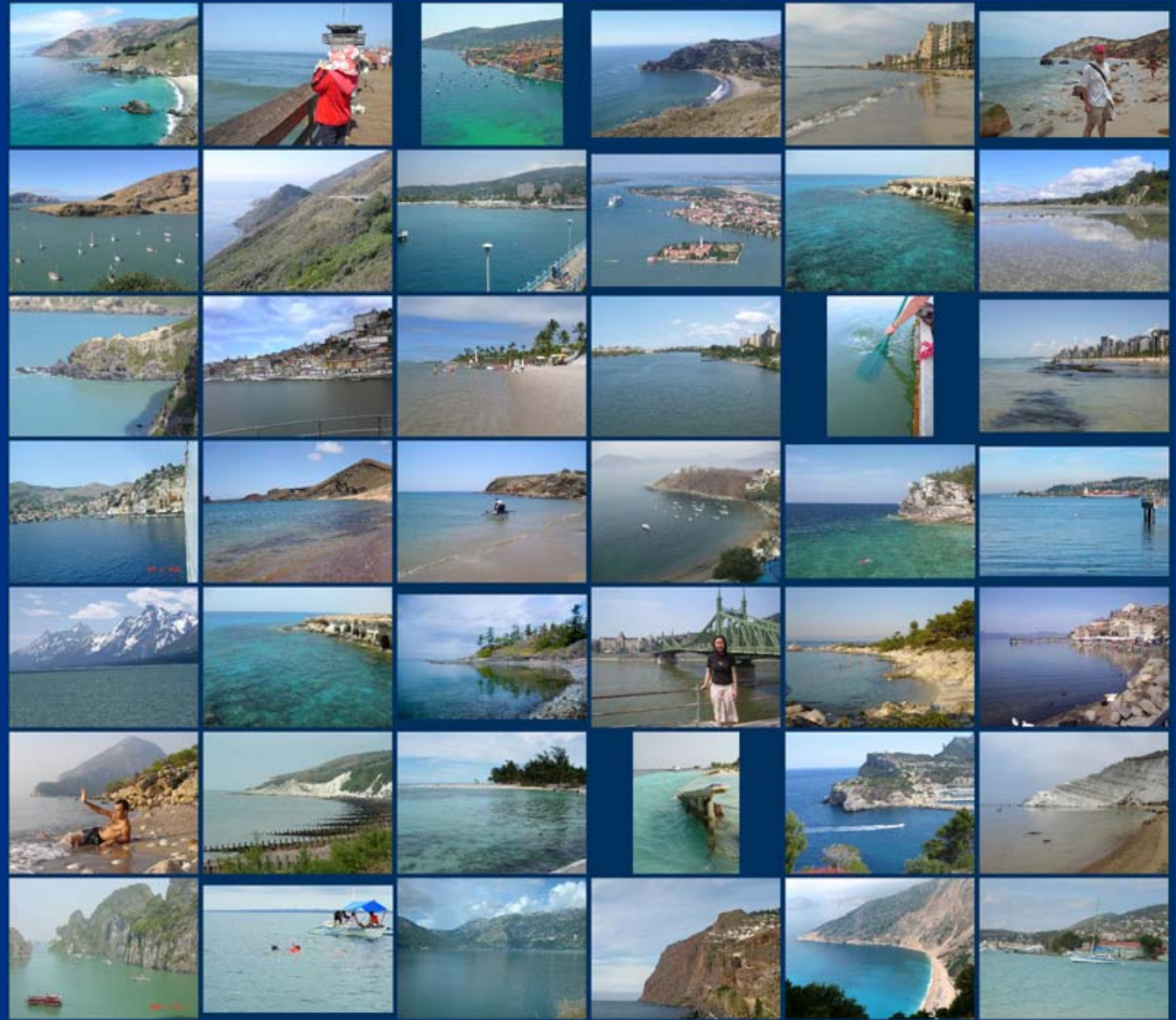
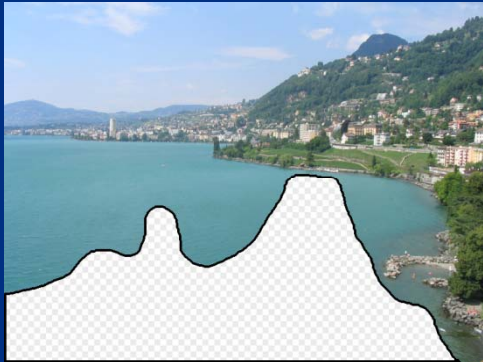


+



Gist scene descriptor  
(Oliva and Torralba 2001)

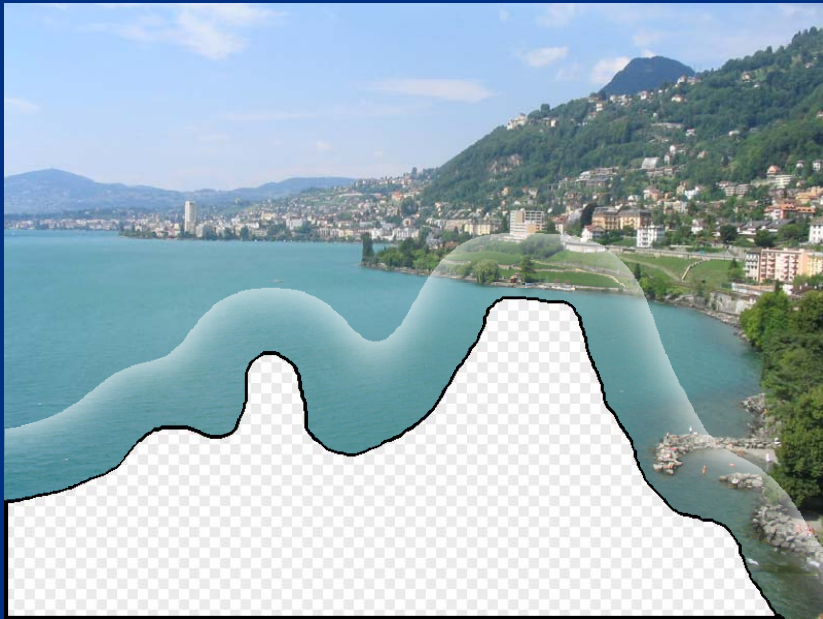




... 200 total



# Context Matching



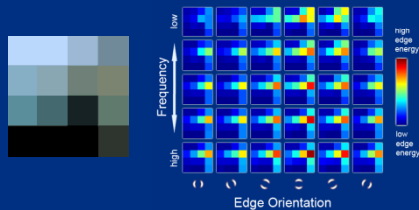


Graph cut + Poisson blending

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)

# Top 20 Results





























... 200 scene matches

Hays and Efros, SIGGRAPH 2007





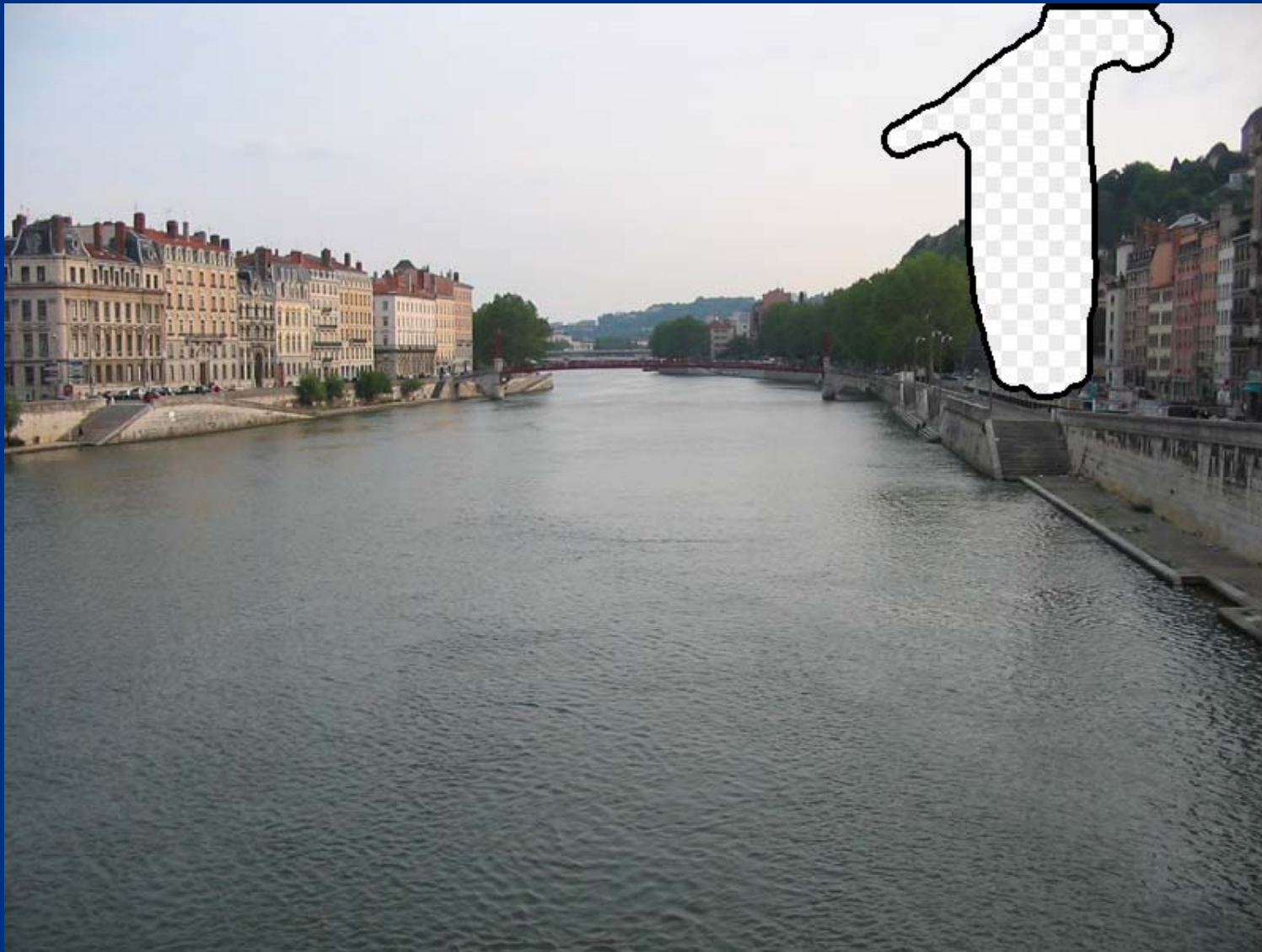
... 200 scene matches

Hays and Efros, SIGGRAPH 2007

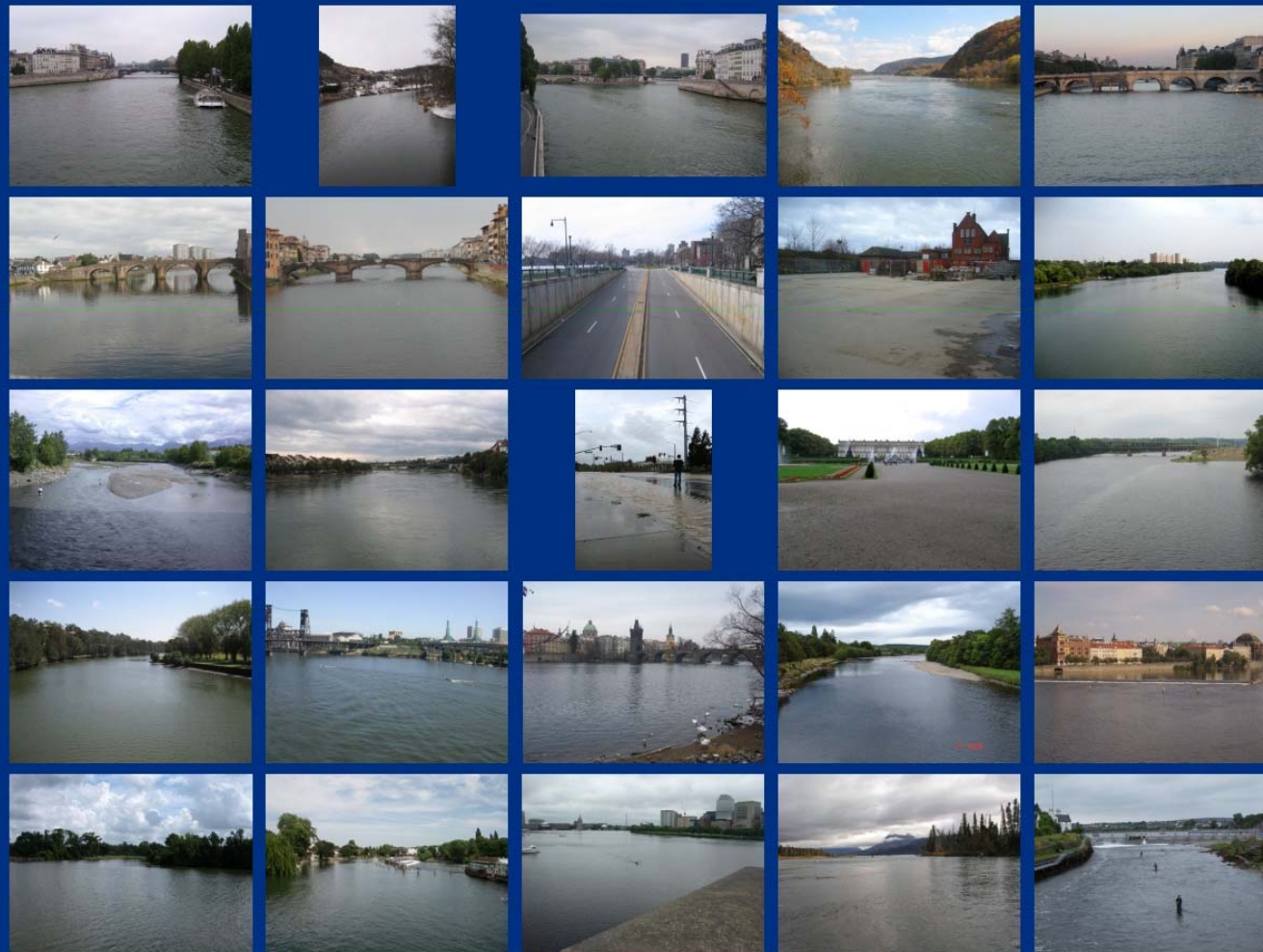
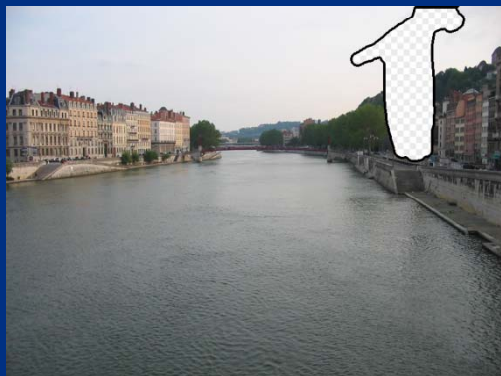




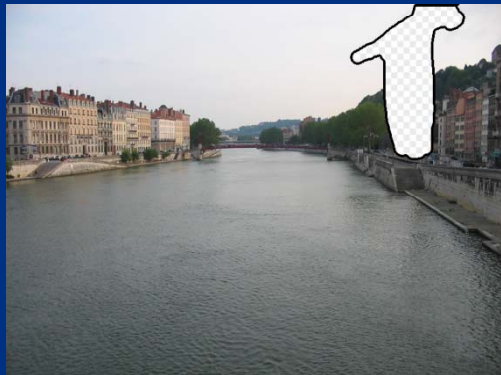






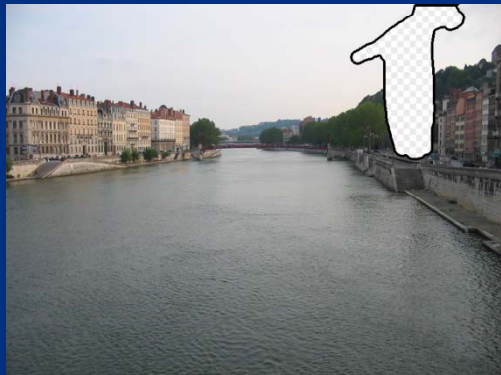


... 200 scene matches

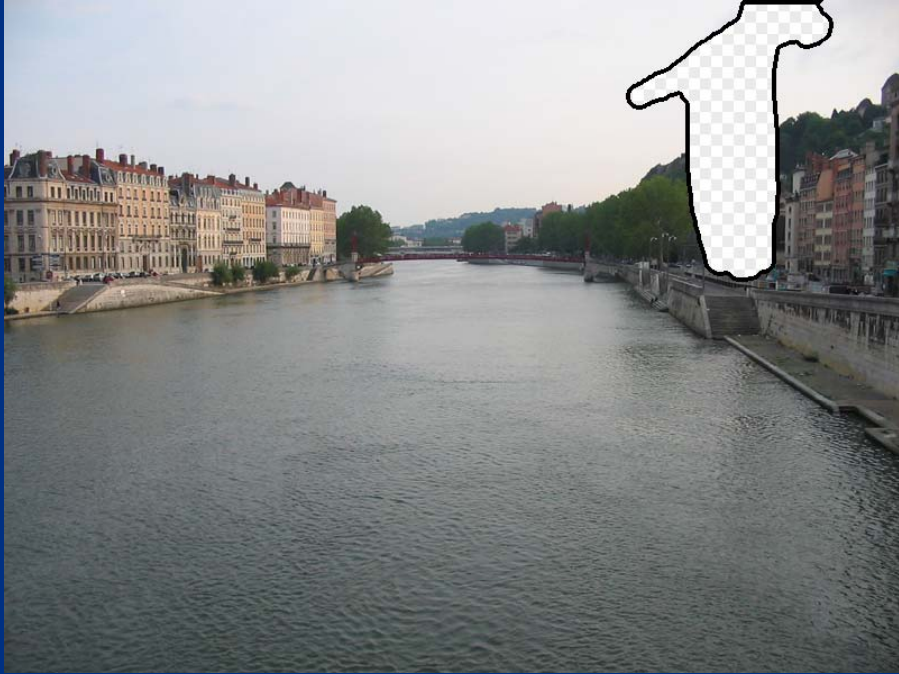


... 200 scene matches





... 200 scene matches



















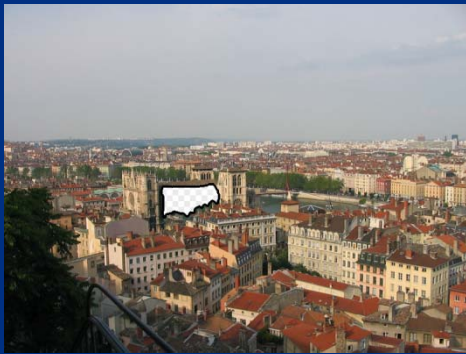




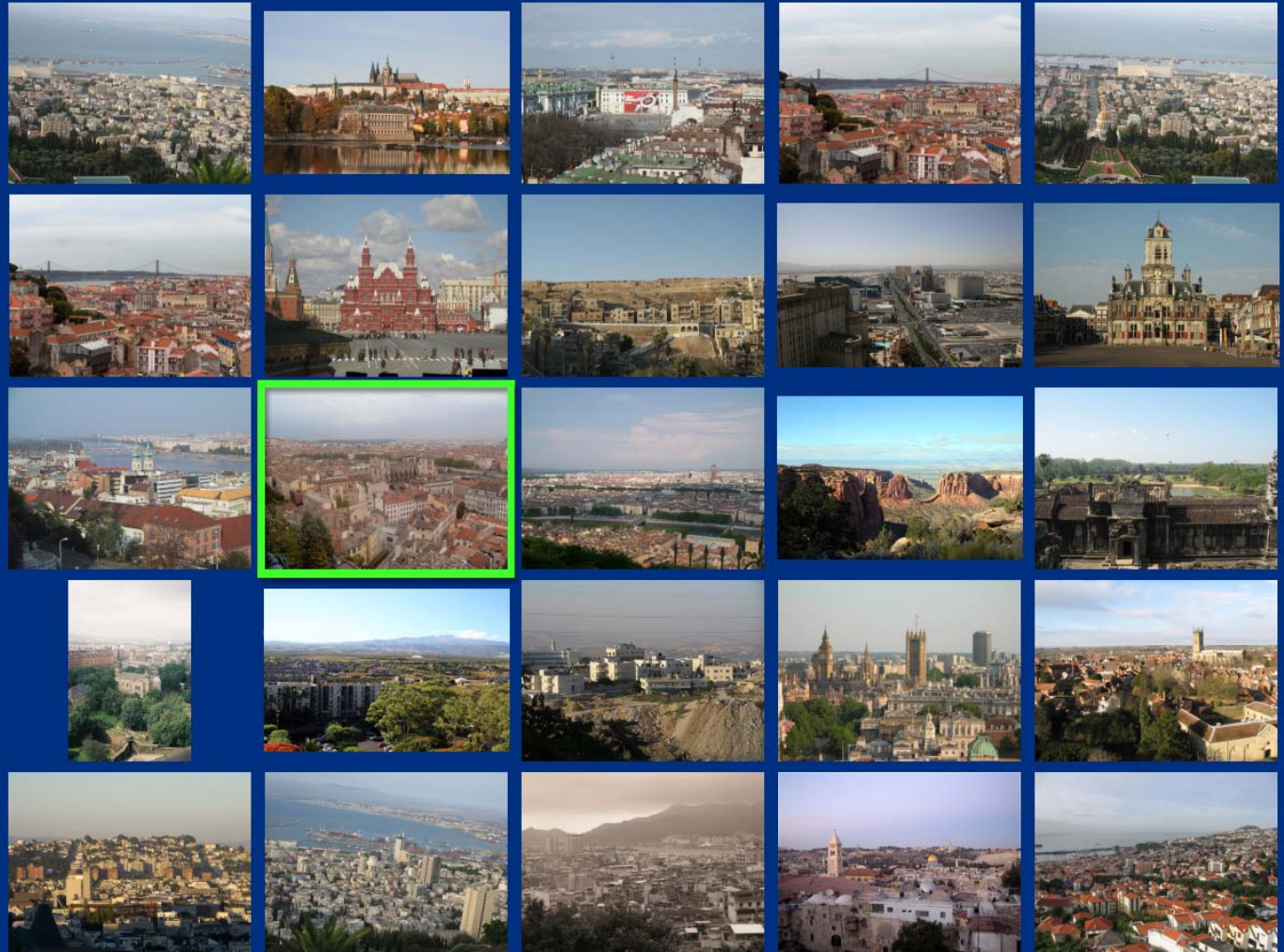
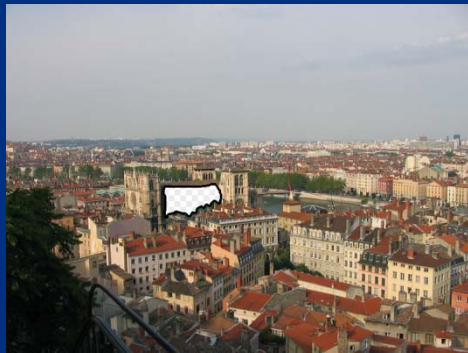






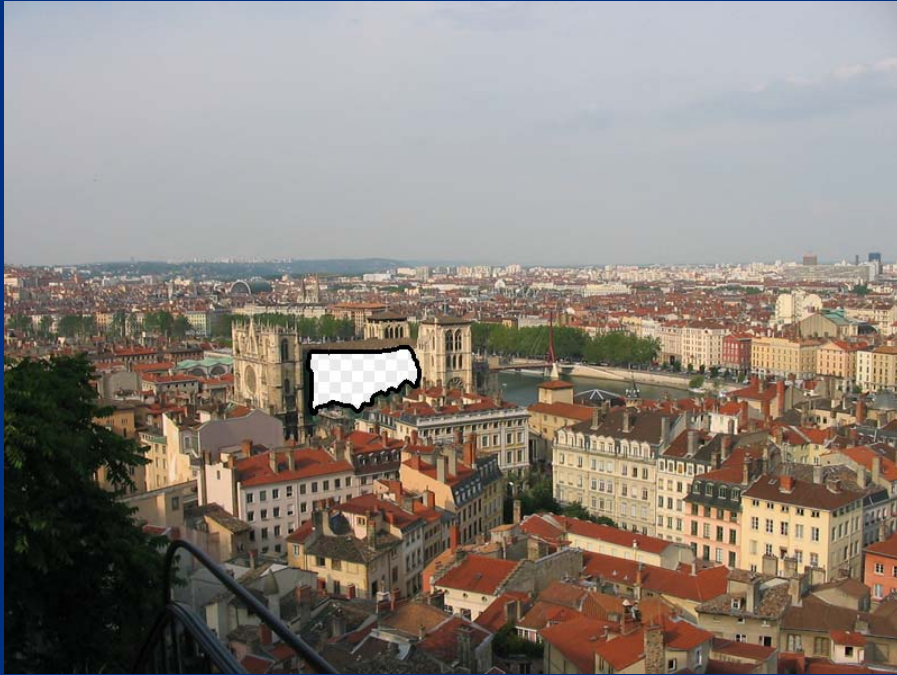


... 200 scene matches



... 200 scene matches







# Failures



# Failures



# Failures



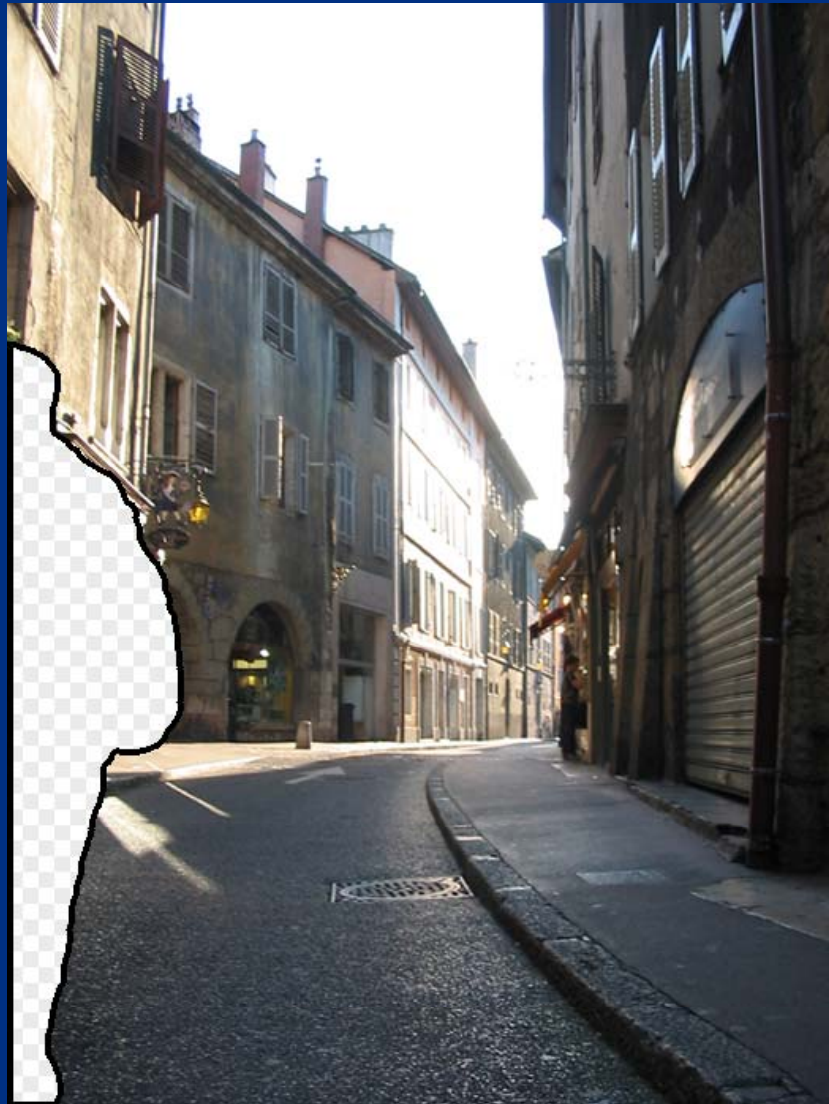
# Failures



# Failures

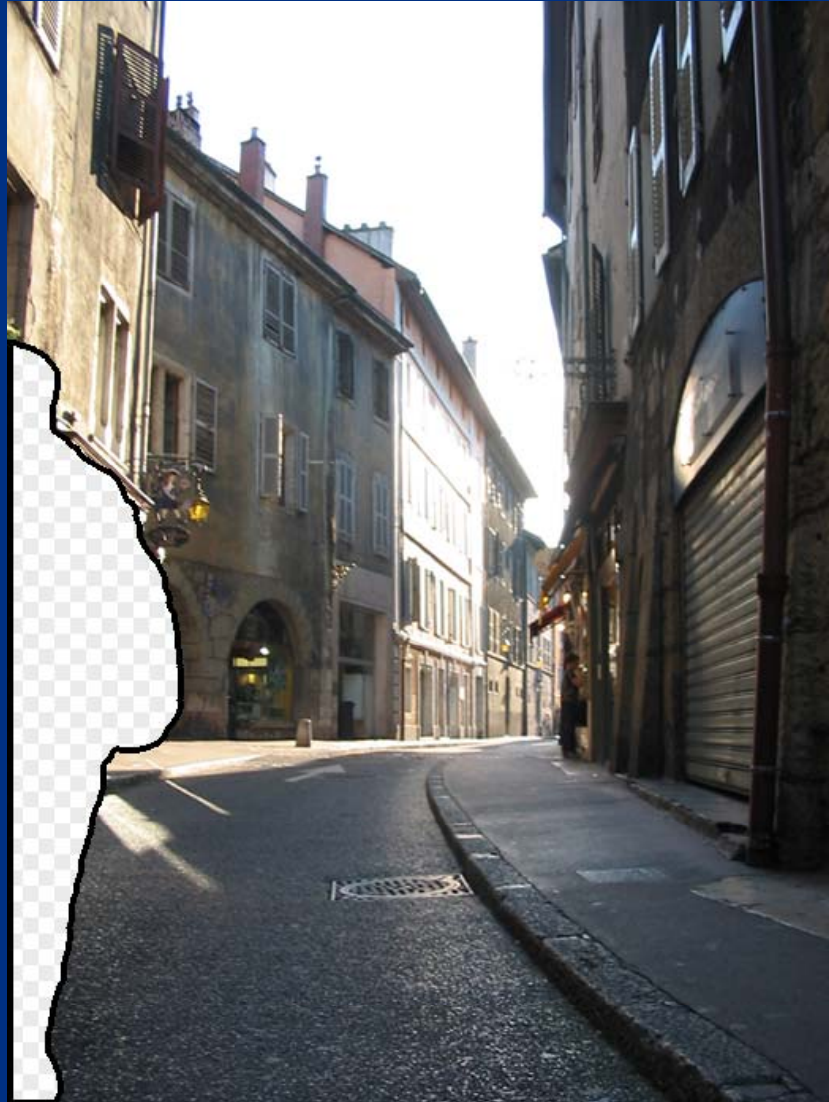


# Failures

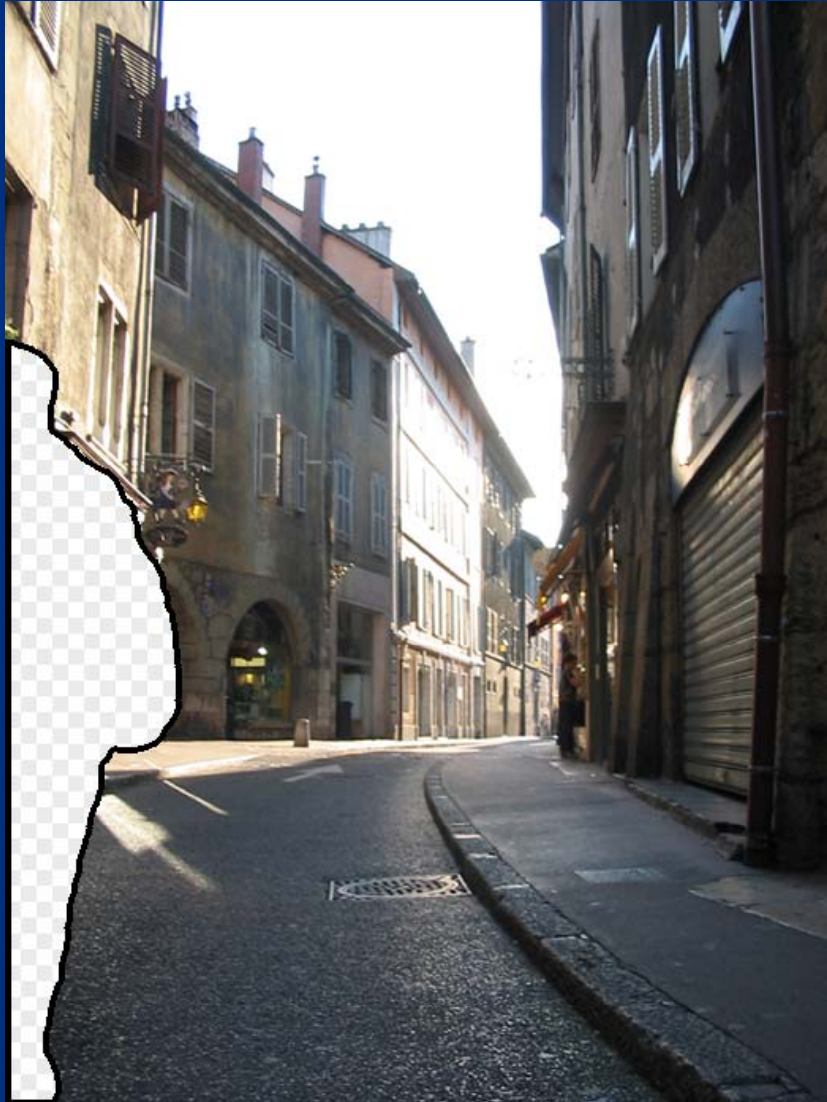




# Failures



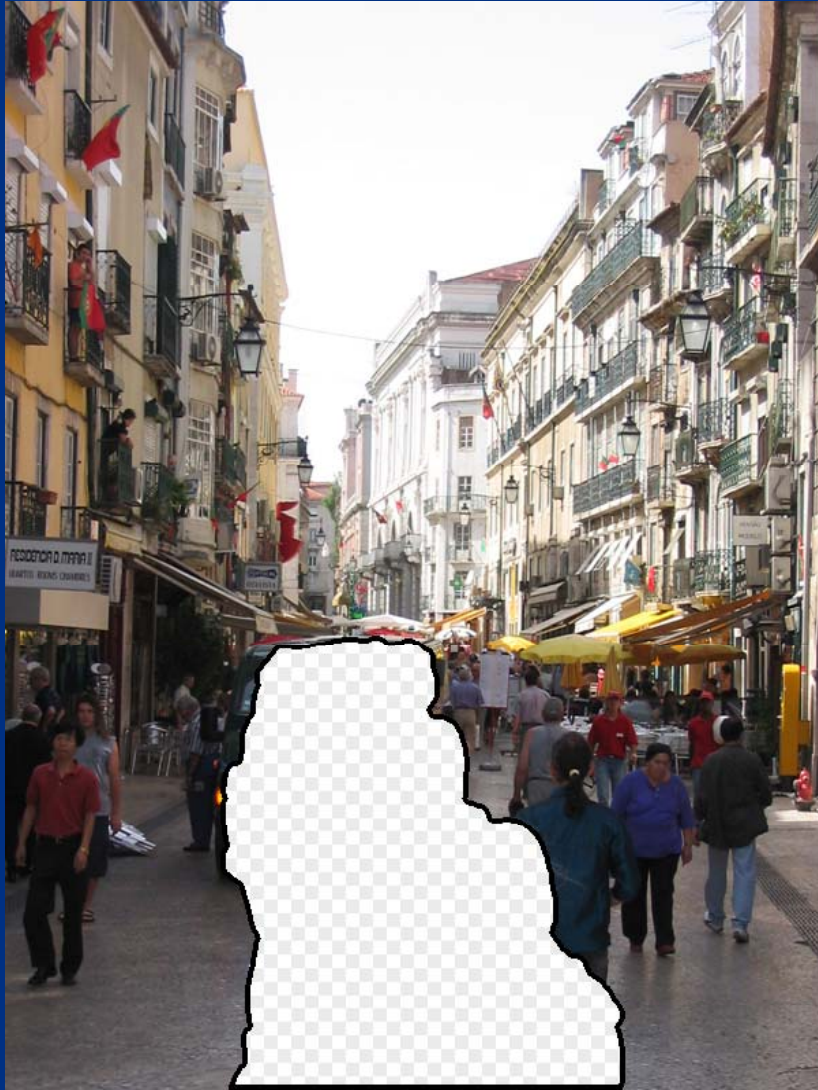
# Failures



# Failures



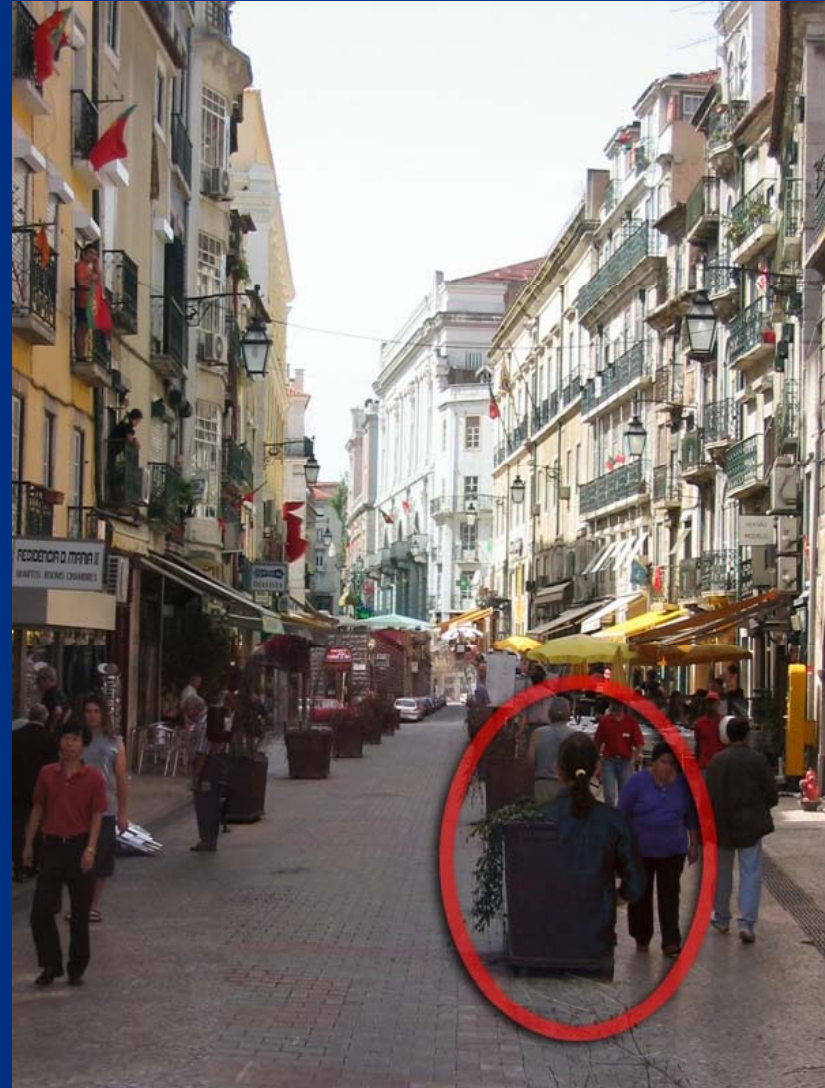
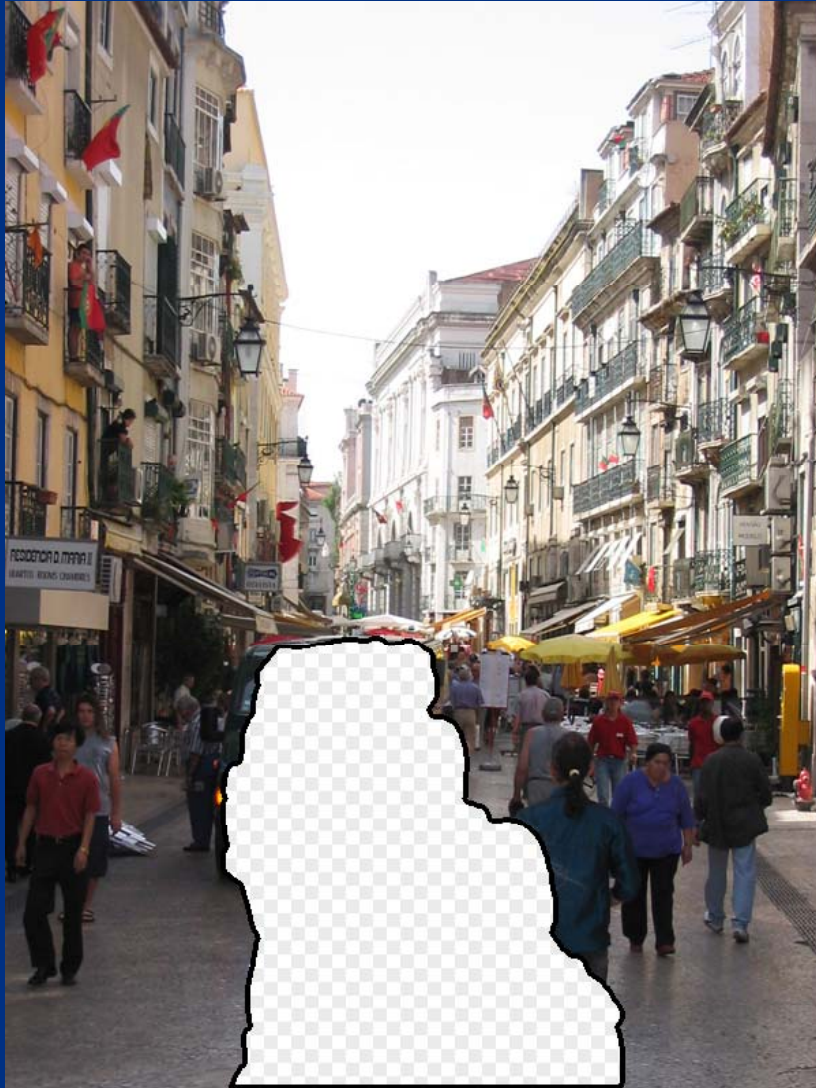
# Failures



# Failures



# Failures



# Evaluation







Original Images



Criminisi et al.

Single result



Scene Completion

Each result  
selected from 20



Original Images

Criminisi et al.

Scene Completion

Single result

Each result  
selected from 20



Real Image. This image  
has not been manipulated

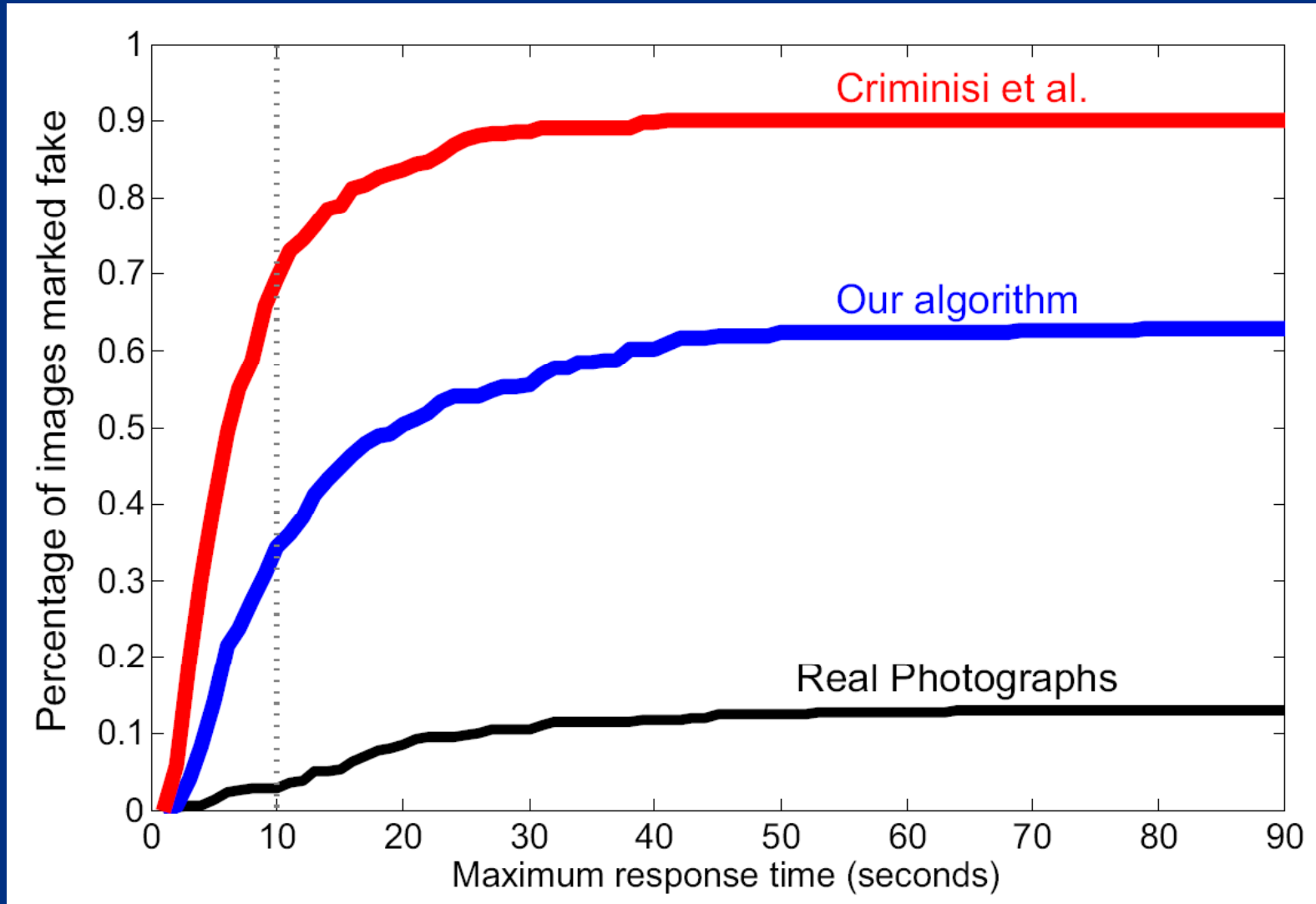
or

Fake Image. This image  
has been manipulated

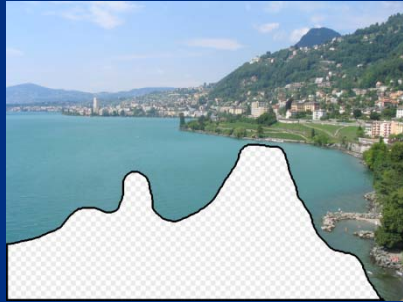




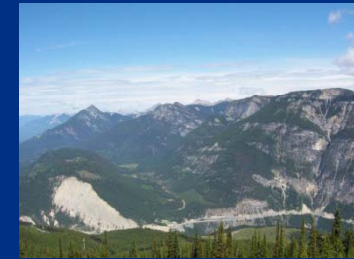
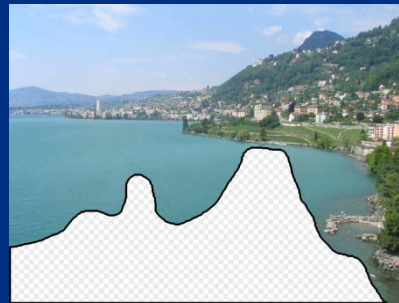
# User Study Results - 20 Participants



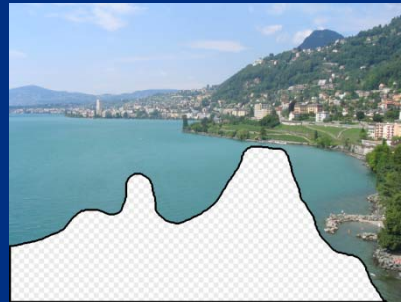
Why does it work?







10 nearest neighbors from a collection of 20,000 images



10 nearest neighbors from a collection of 2 million images

# The Small Picture

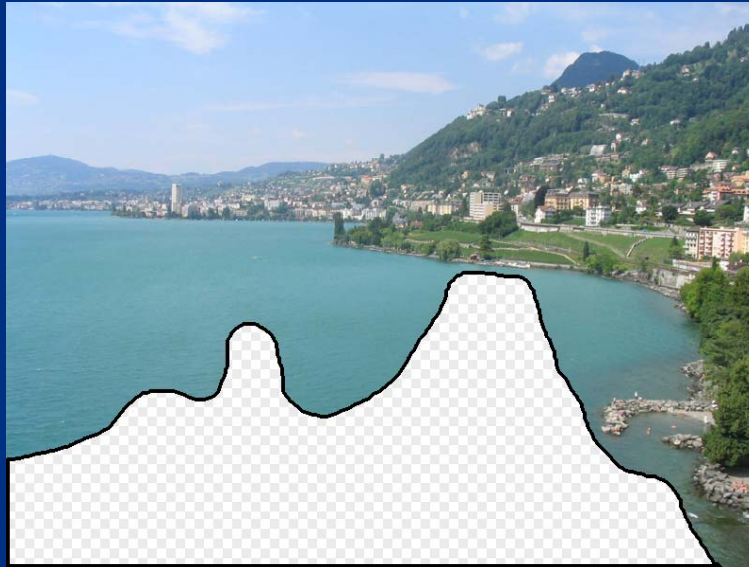
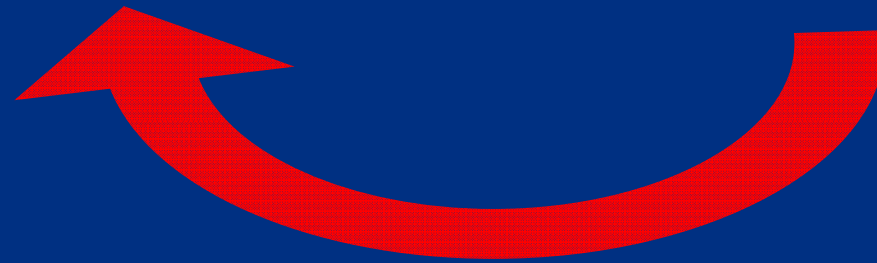


Image Collection



Pixels



Pixels + Semantics

# Expert-supplied Semantics



# Hybrid Solution?

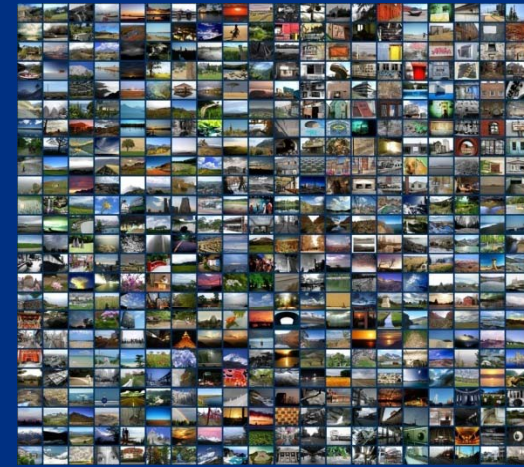
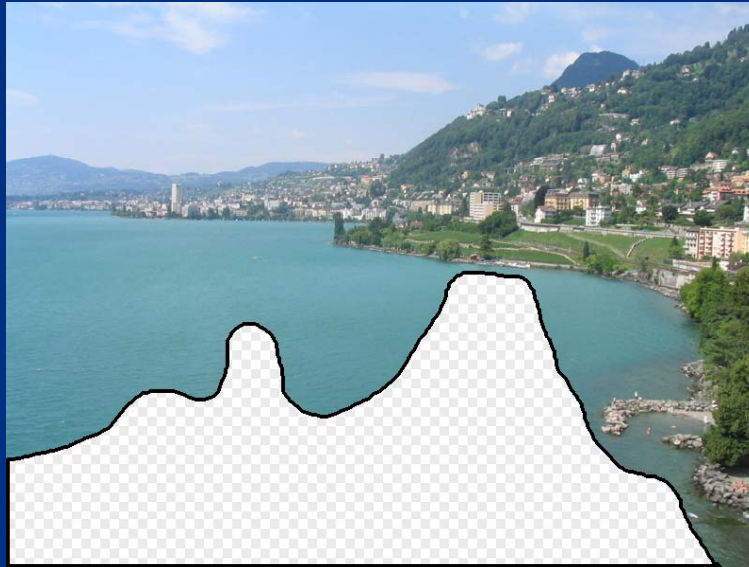
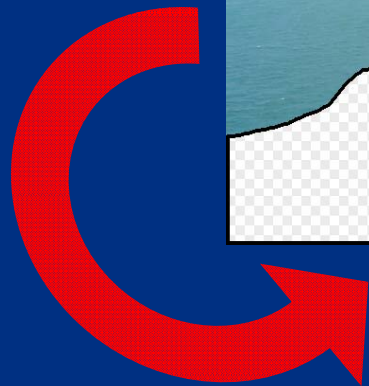
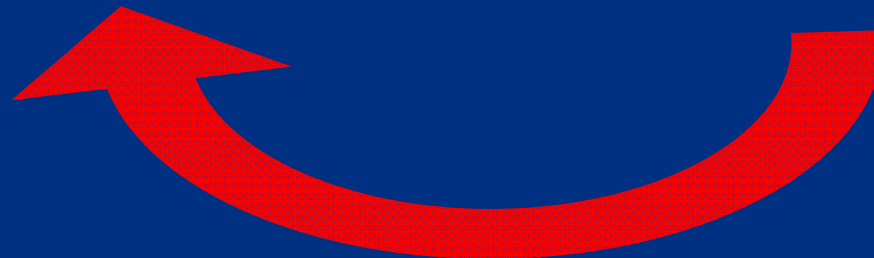


Image Collection



Pixels



Semantics

# The Big Picture



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

Brute-force Image Understanding



# Thank You! We also thank...

Antonio Torralba and Aude Oliva for Gist code.

Rob Fergus for his image downloading scripts.

Gabriel Brostow for their image completion software.

Tamera Berg and Alex Berg for their Flickr API scripts.

Vladimir Kolmogorov for Graph cut optimization code.

Amit Agrawal for Poisson blending code.

NSF for funding.

Intel for Computers