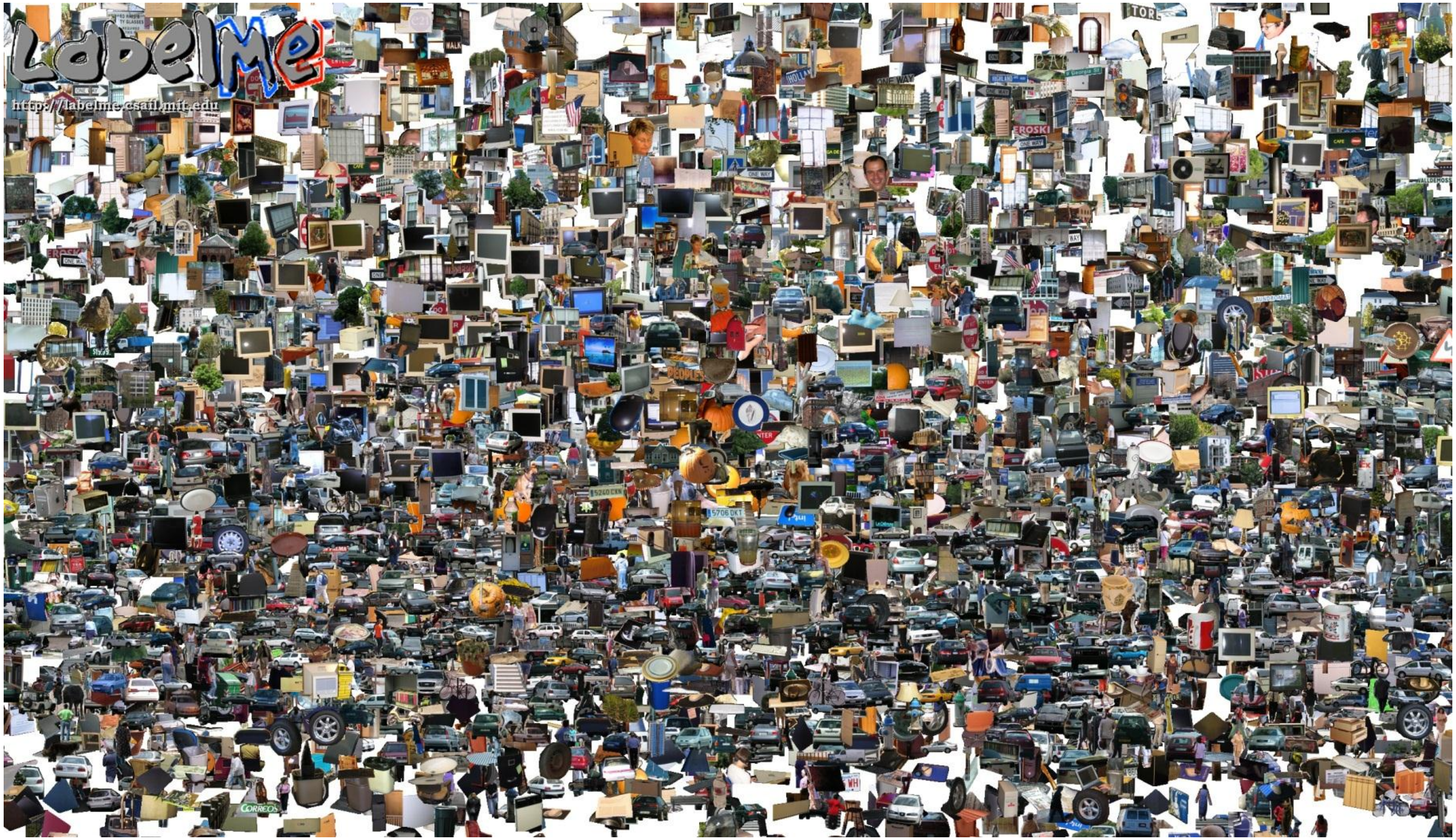
Opportunities of Scale



Computer Vision

Derek Hoiem, University of Illinois

Many slides from Alyosha Efros

Graphic from Antonio Torralba

Today's class

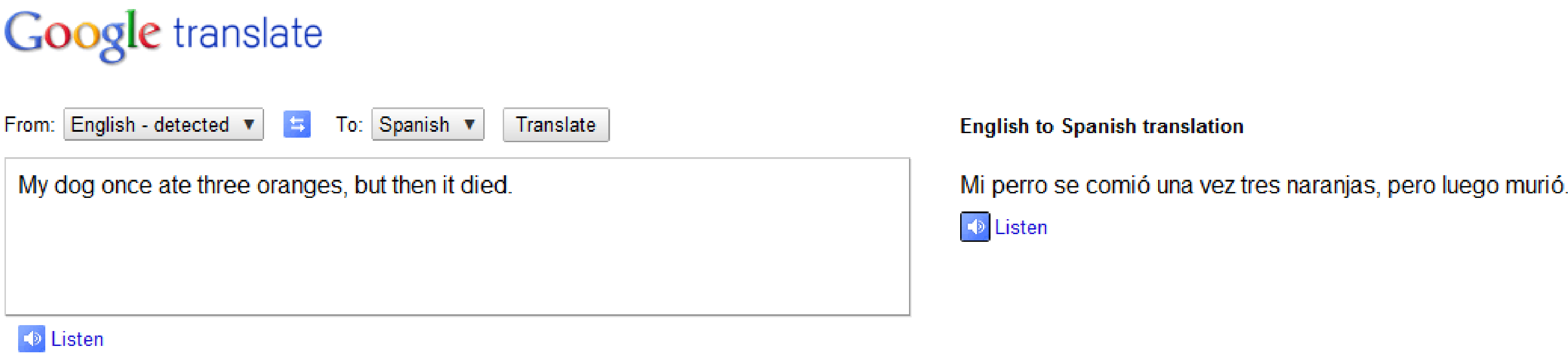
- Opportunities of Scale: Data-driven methods
  - Scene completion
  - Im2gps
  - Recognition via Tiny Images
  - More recognition by association

Google and massive data-driven algorithms

A.I. for the postmodern world:

- all questions have already been answered…many times, in many ways
- Google is dumb, the "intelligence" is <u>in the data</u>

Google Translate



Chinese Room

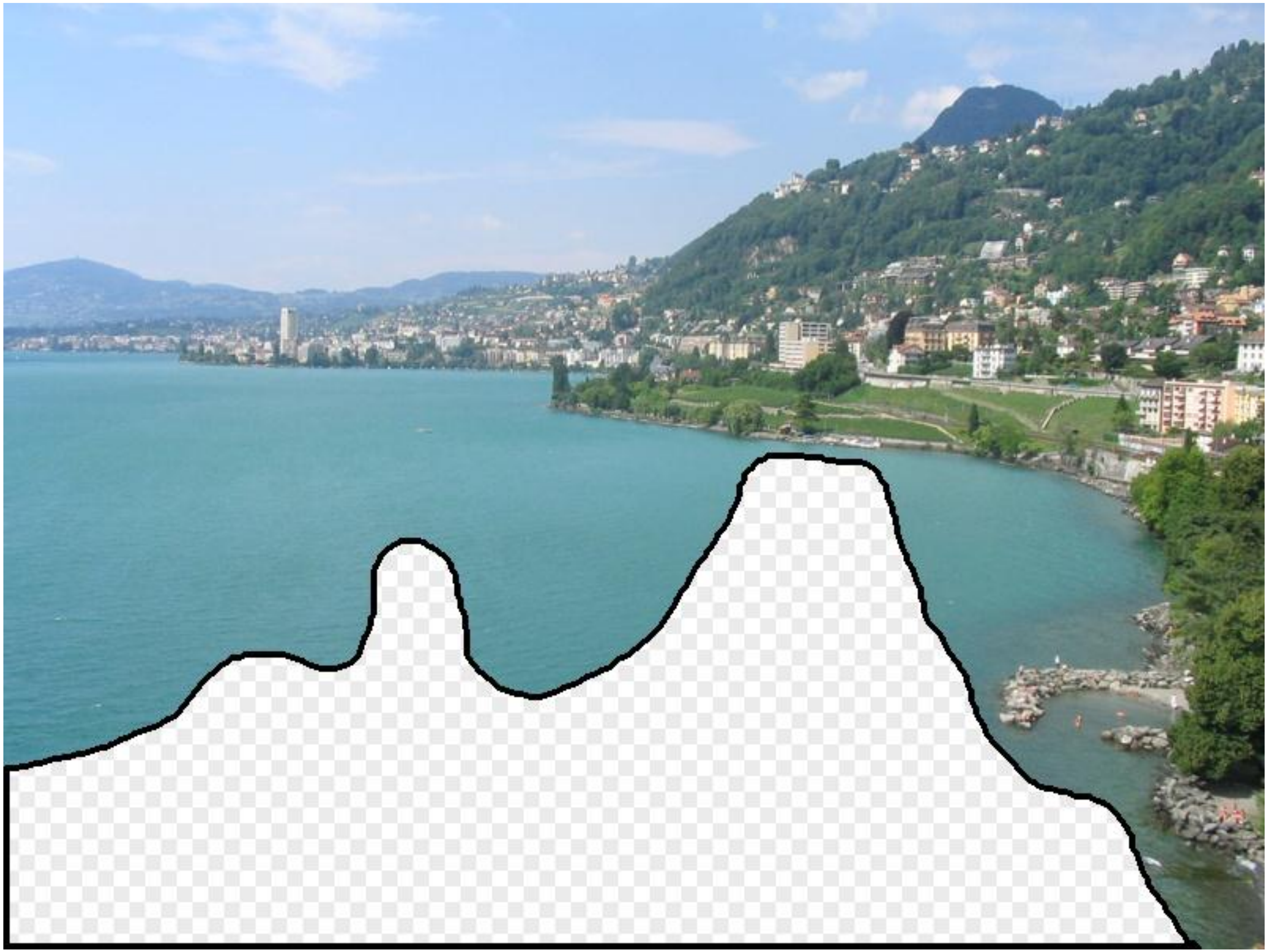
- John Searle (1980)

Image Completion Example

[Hays and Efros. Scene Completion Using Millions of Photographs. SIGGRAPH 2007 and CACM October 2008.]

http://graphics.cs.cmu.edu/projects/scene-completion/

What should the missing region contain?



Which is the original?

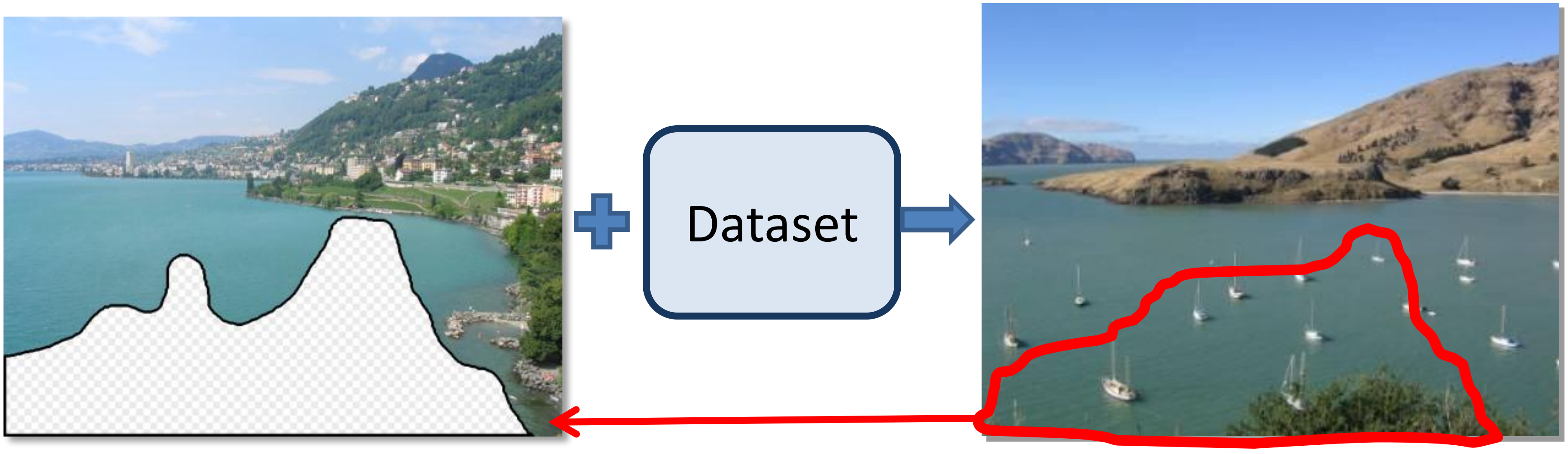
(a)

(b)

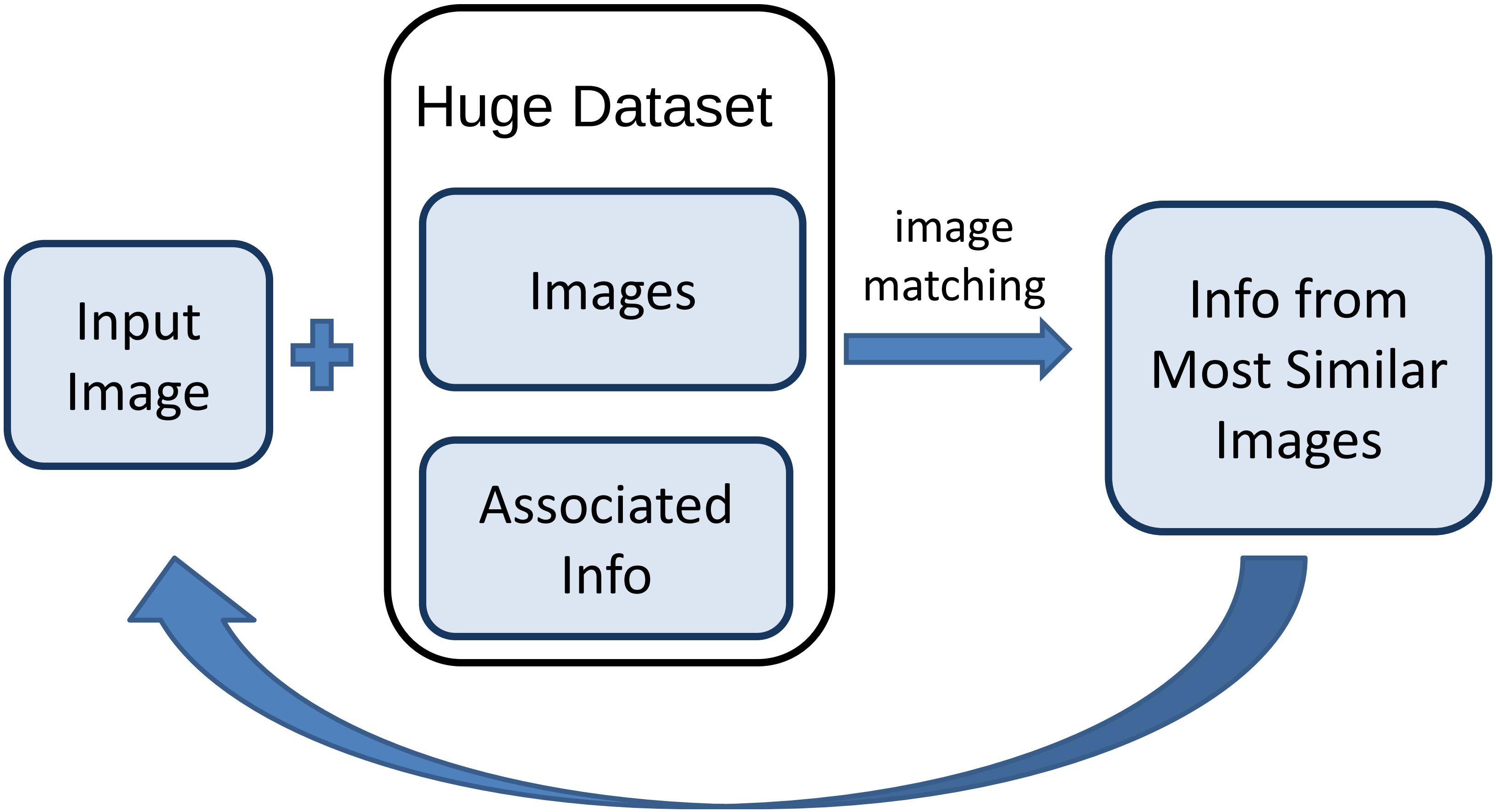
(c)

How it works

- Find a similar image from a large dataset
- Blend a region from that image into the hole

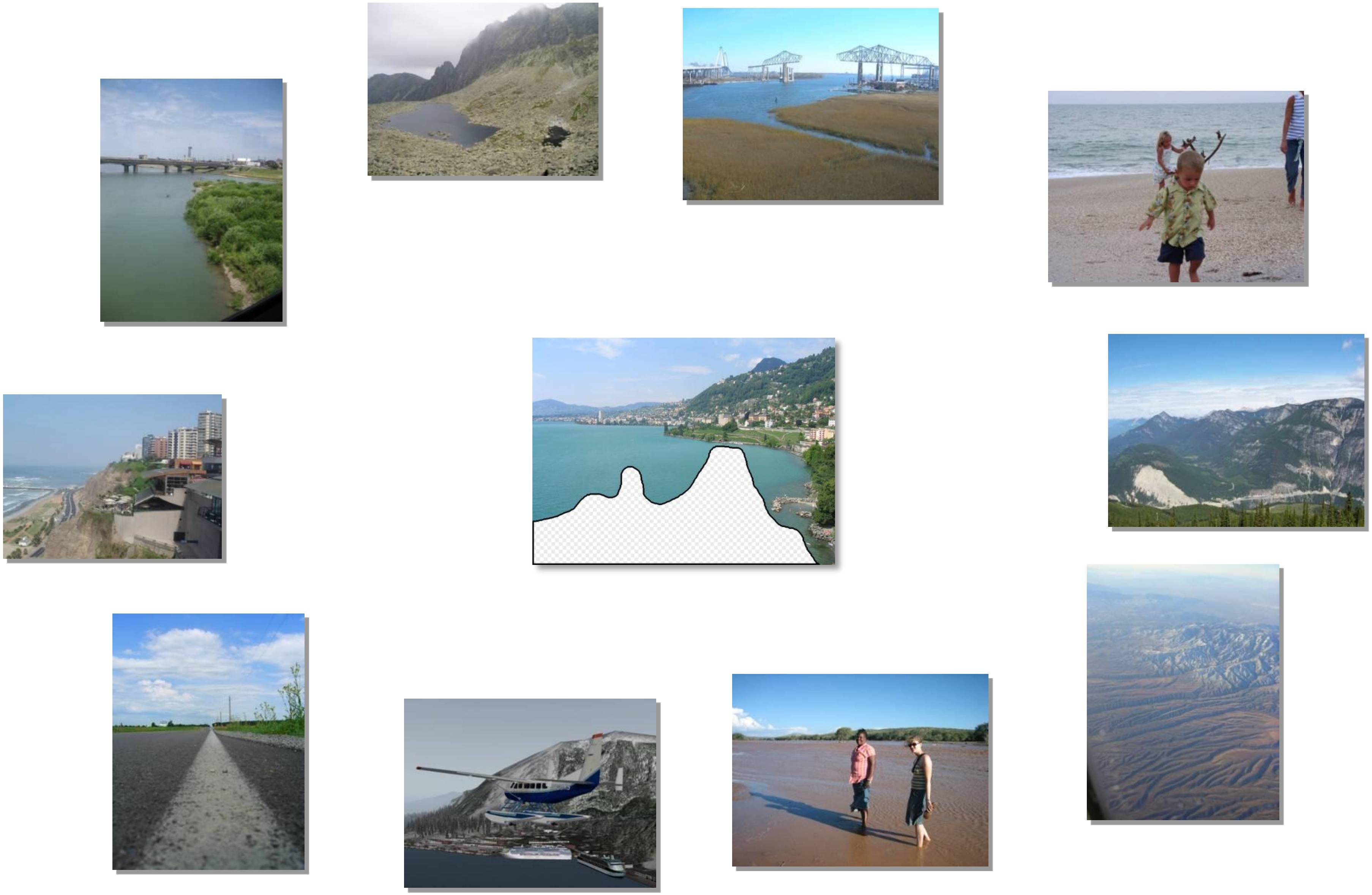


General Principal

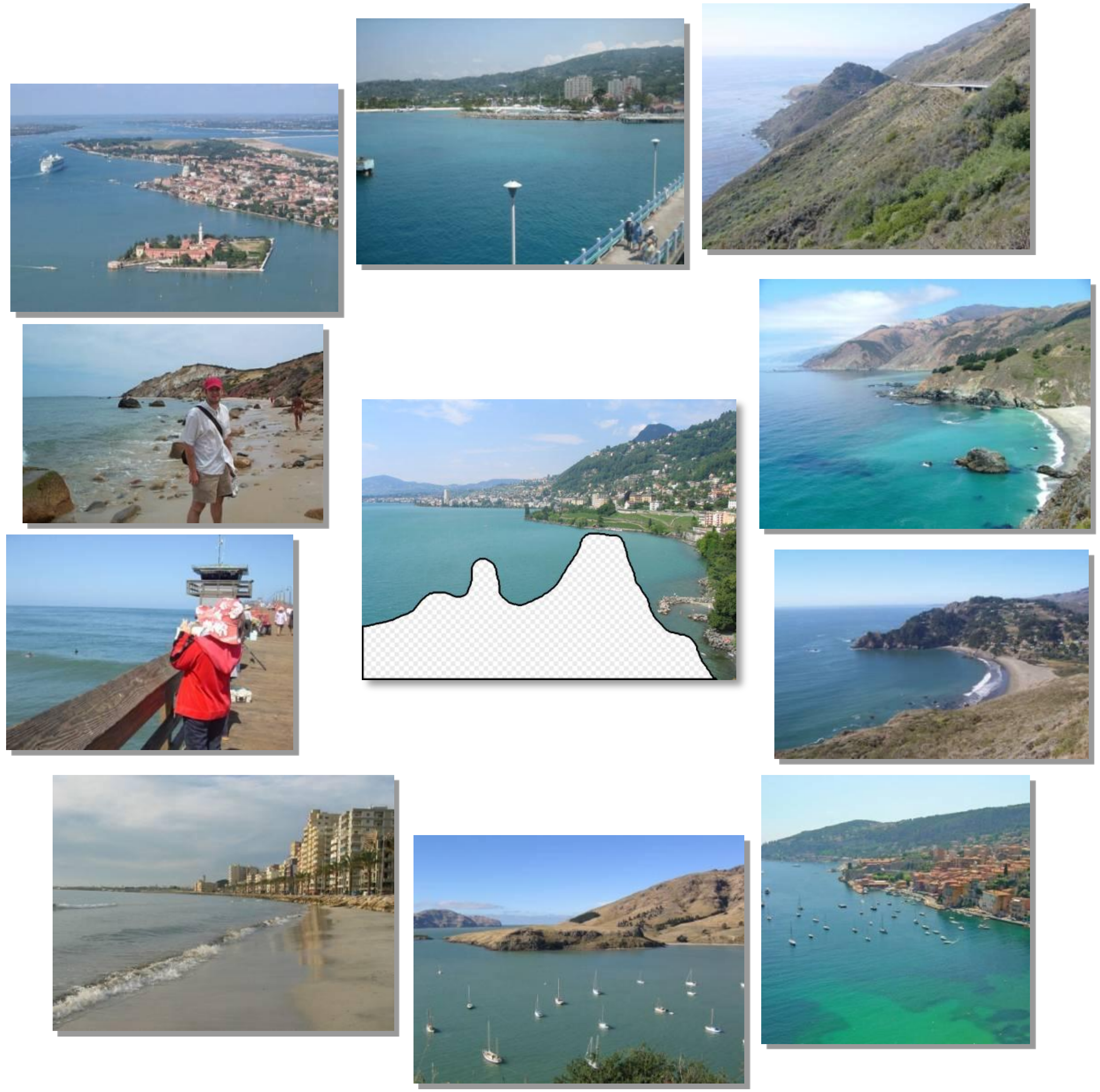


Trick: If you have enough images, the dataset will contain very similar images that you can find with simple maching methods.

How many images is enough?



Nearest neighbors from a
collection of 20 thousand images



Nearest neighbors from a
collection of 2 million images

Image Data on the Internet

- Flickr (as of Sept. 19th, 2010)
  - 5 billion photographs
  - 100+ million geotagged images
- Imageshack (as of 2009)
  - 20 billion
- Facebook (as of 2009)
  - 15 billion

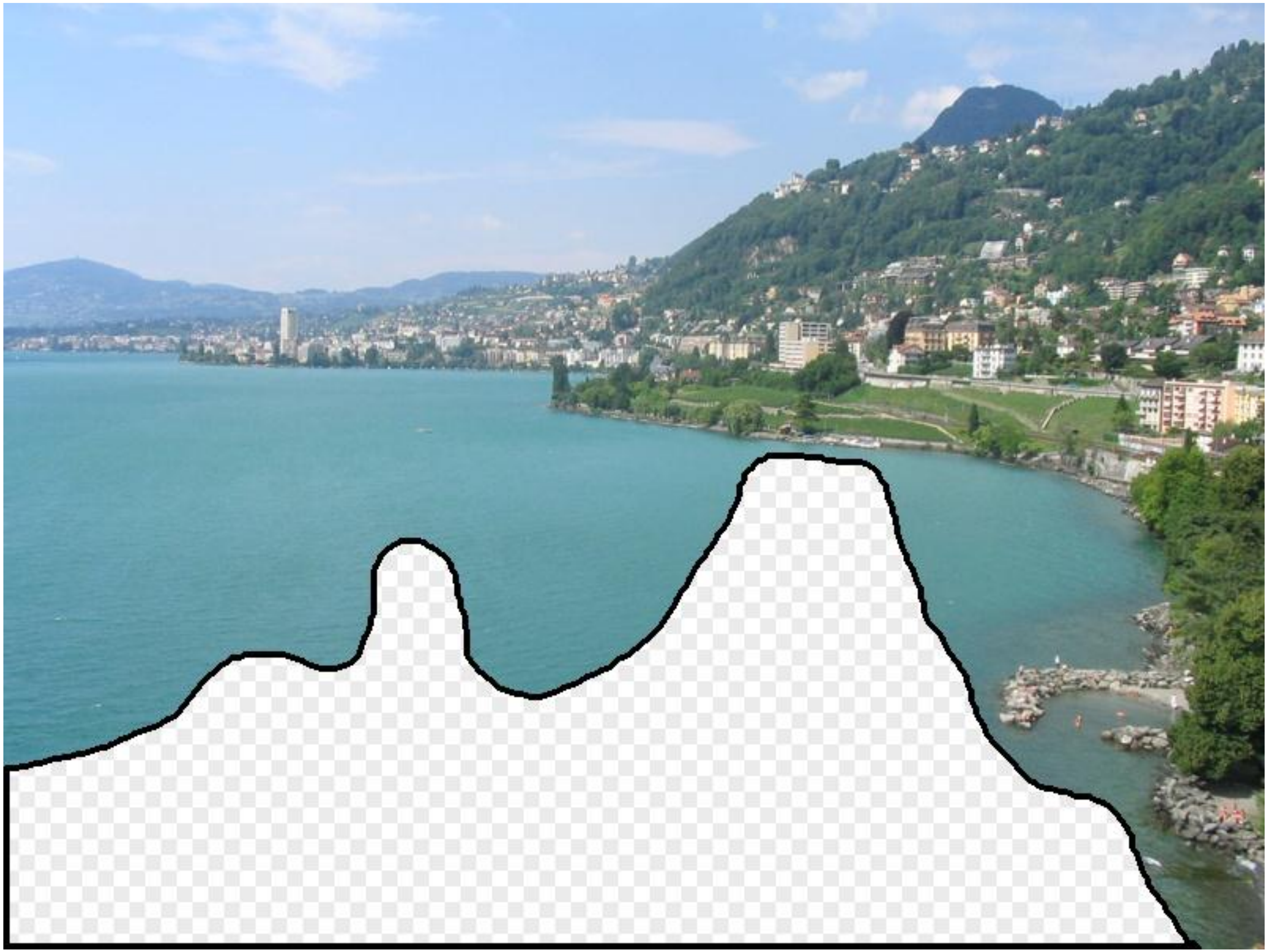
http://royal.pingdom.com/2010/01/22/internet-2009-in-numbers/

Image completion: how it works

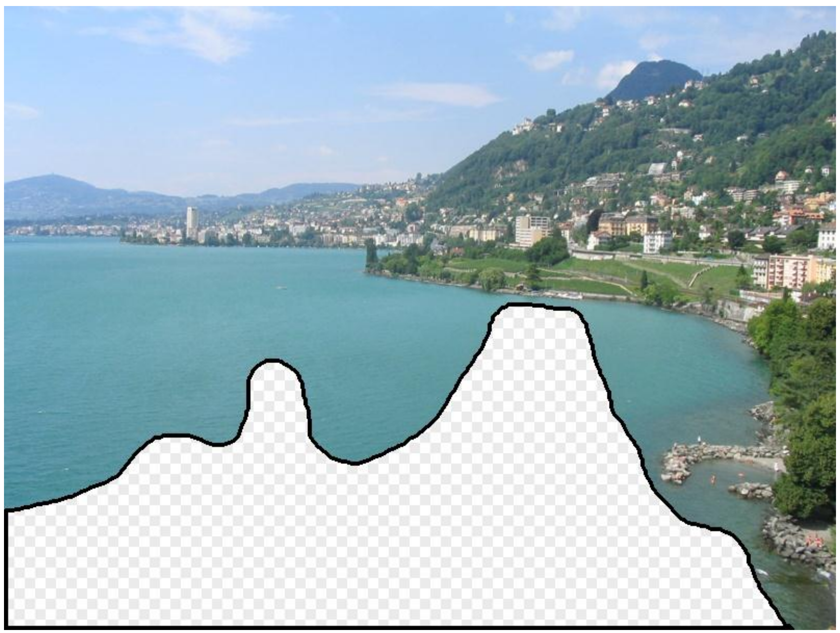
[Hays and Efros. Scene Completion Using Millions of Photographs. SIGGRAPH 2007 and CACM October 2008.]

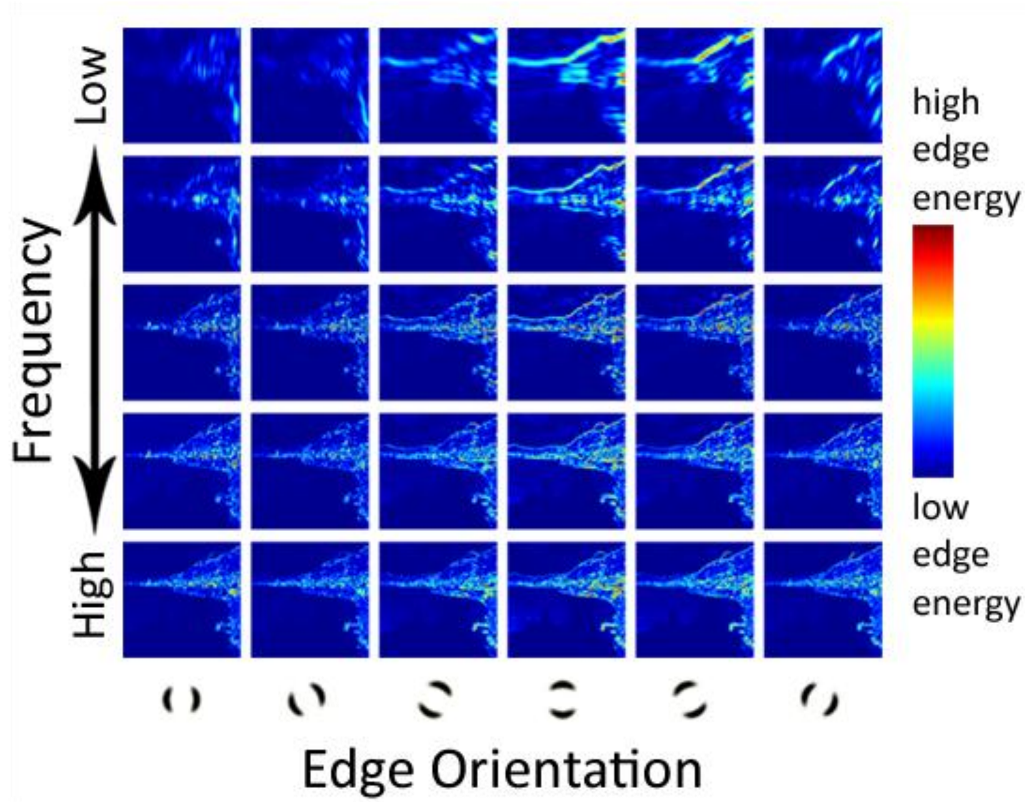
The Algorithm

Scene Matching

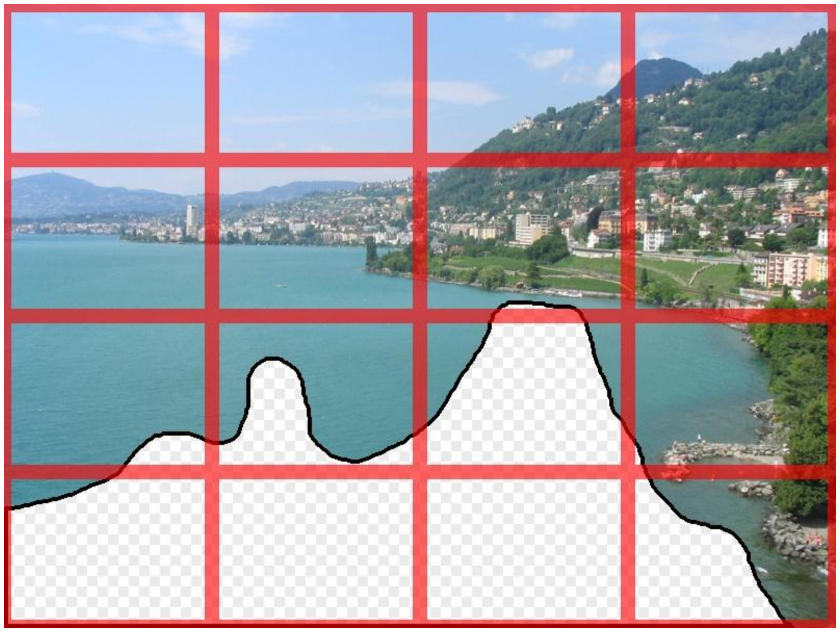


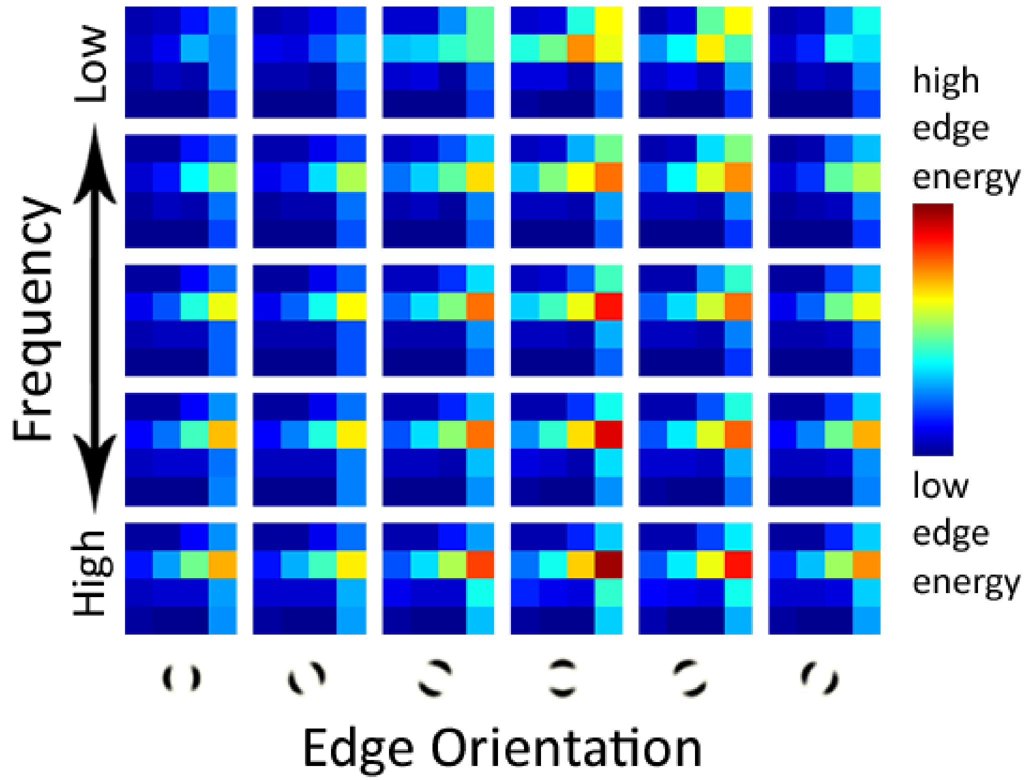
Scene Descriptor





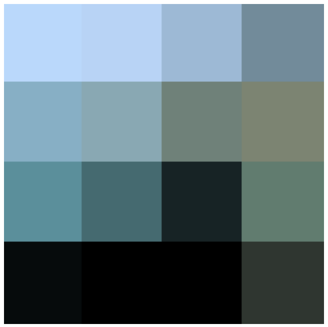
Scene Descriptor



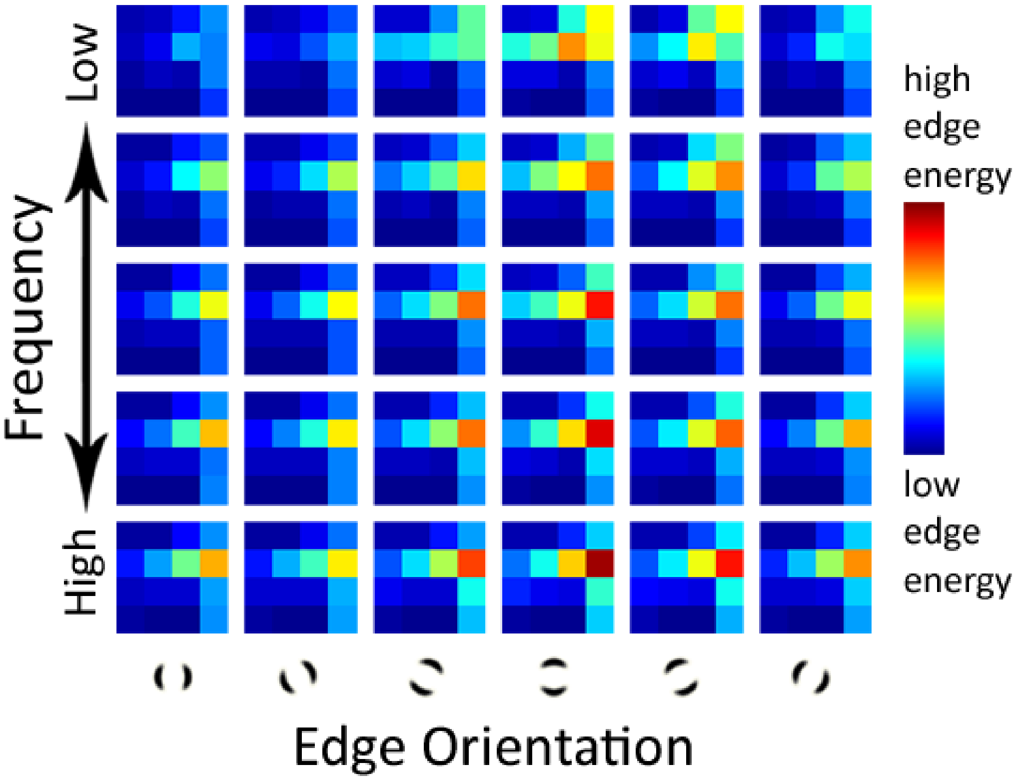


Scene Gist Descriptor
(Oliva and Torralba 2001)

Scene Descriptor

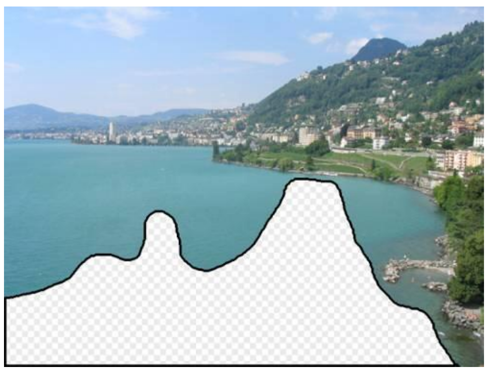


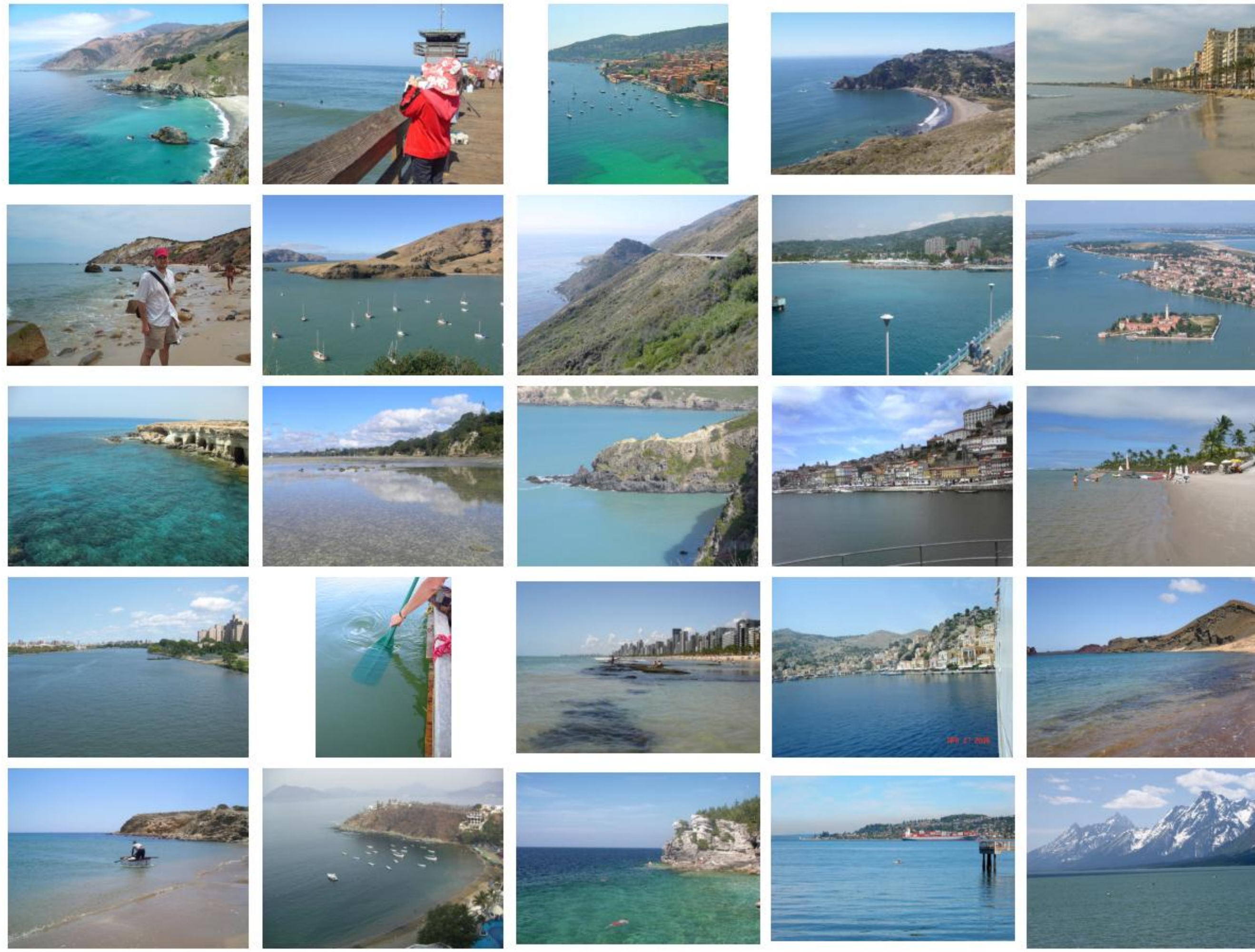
+



Scene Gist Descriptor
(Oliva and Torralba 2001)

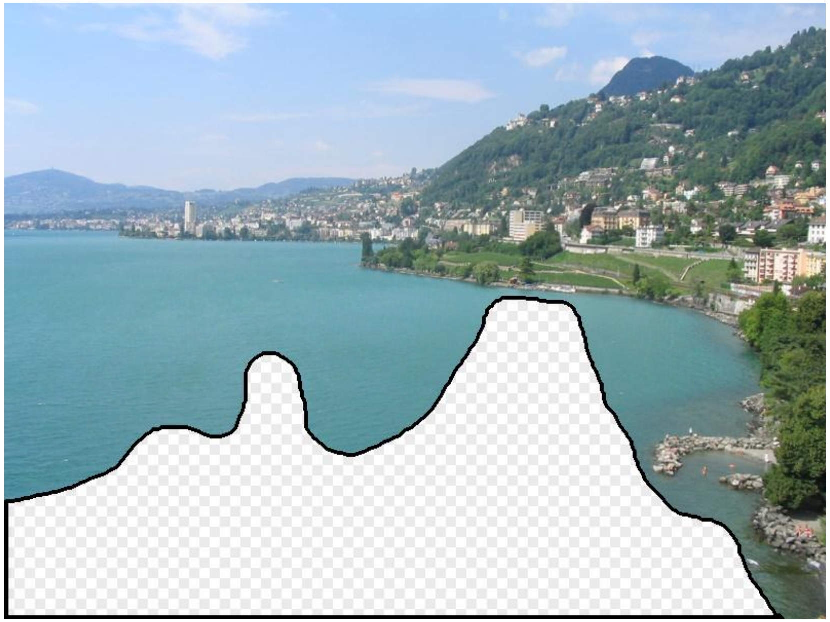
2 Million Flickr Images





… 200 total

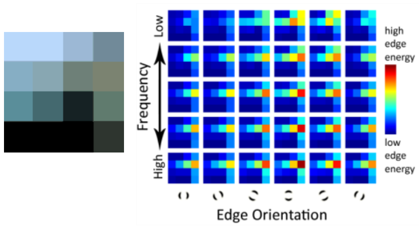
Context Matching



Graph cut + Poisson blending

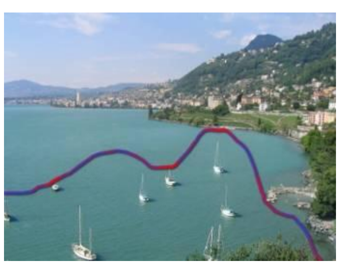
Result Ranking

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

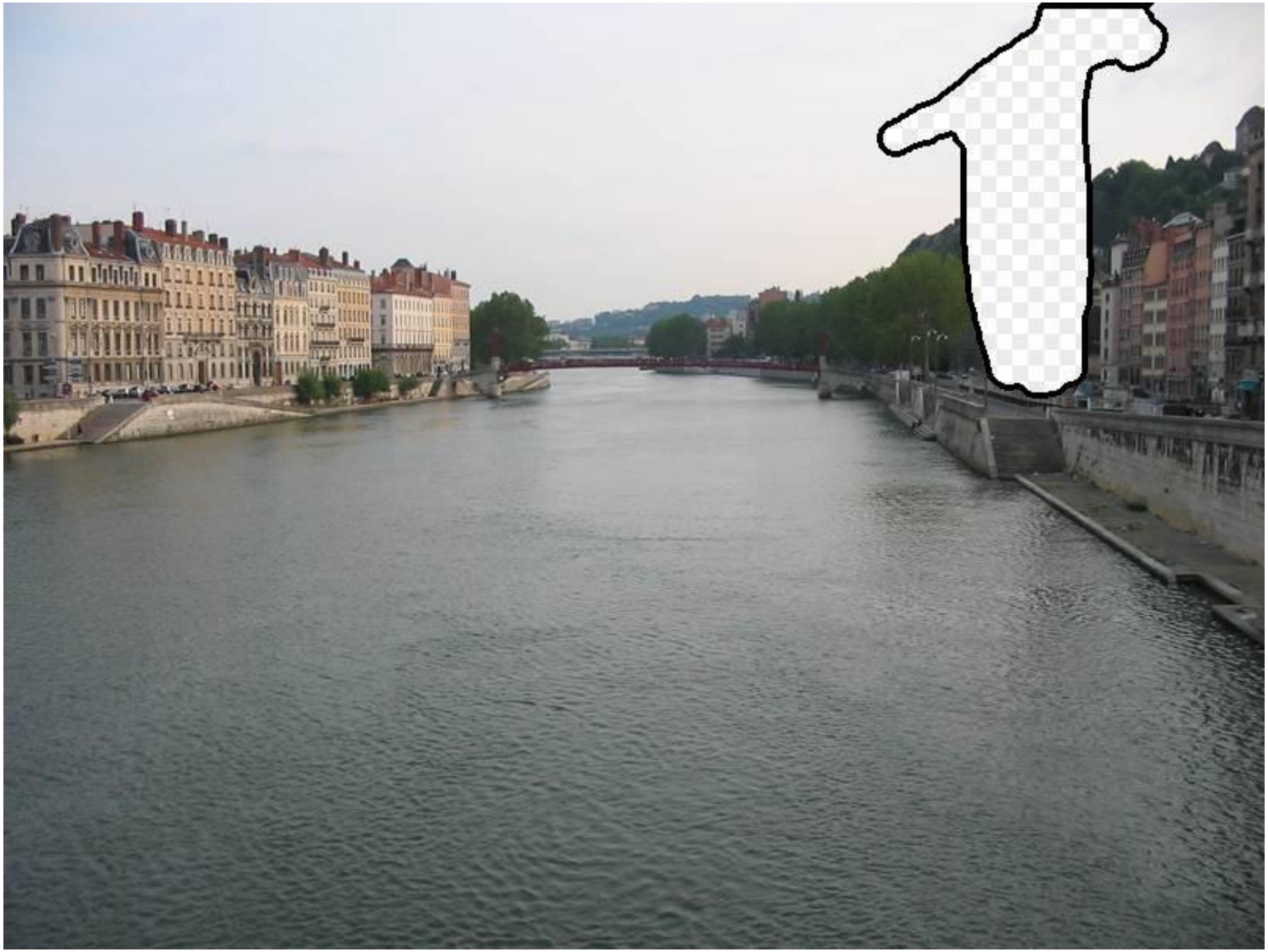


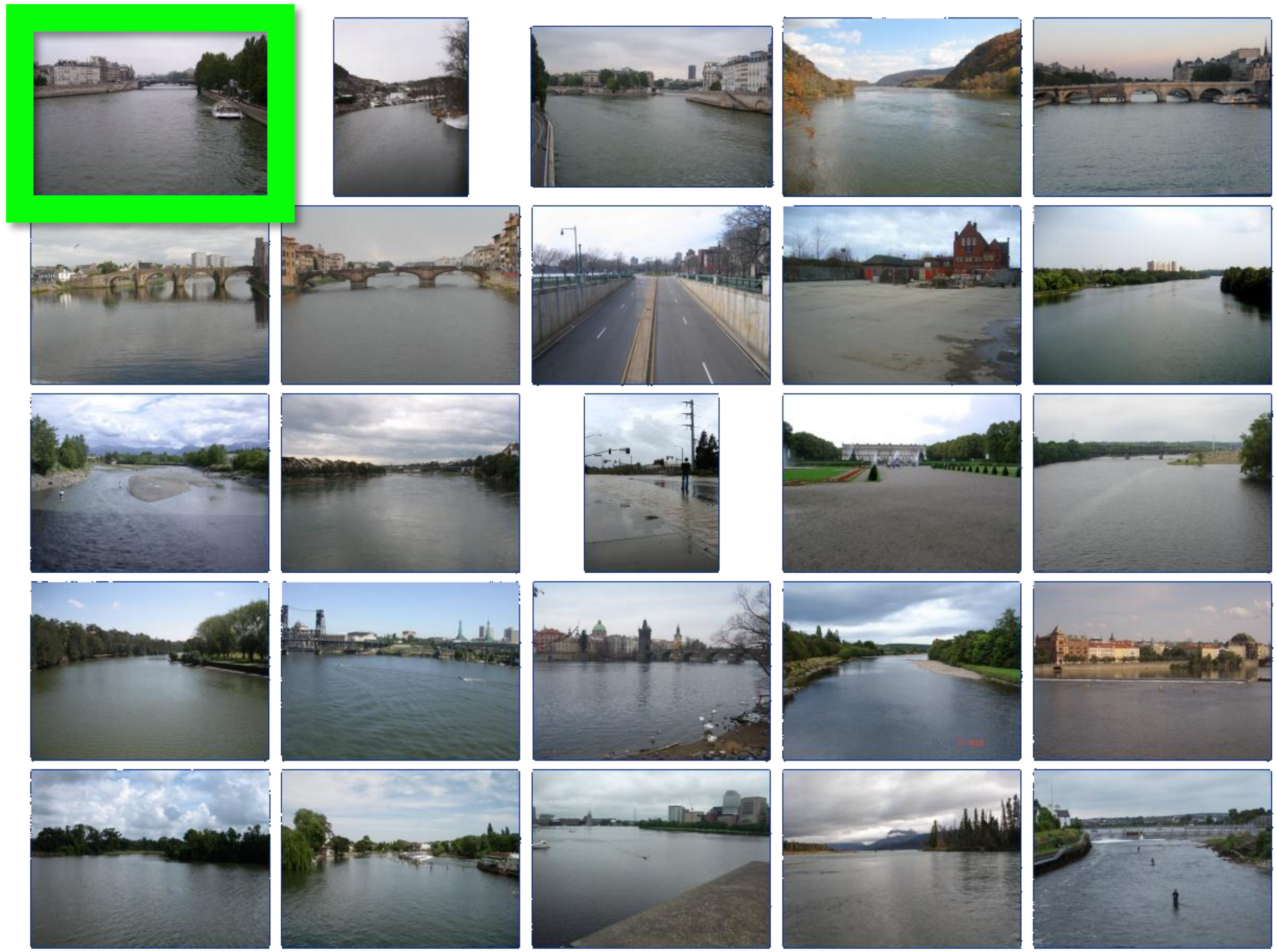
The scene matching distance

The context matching distance (color + texture)

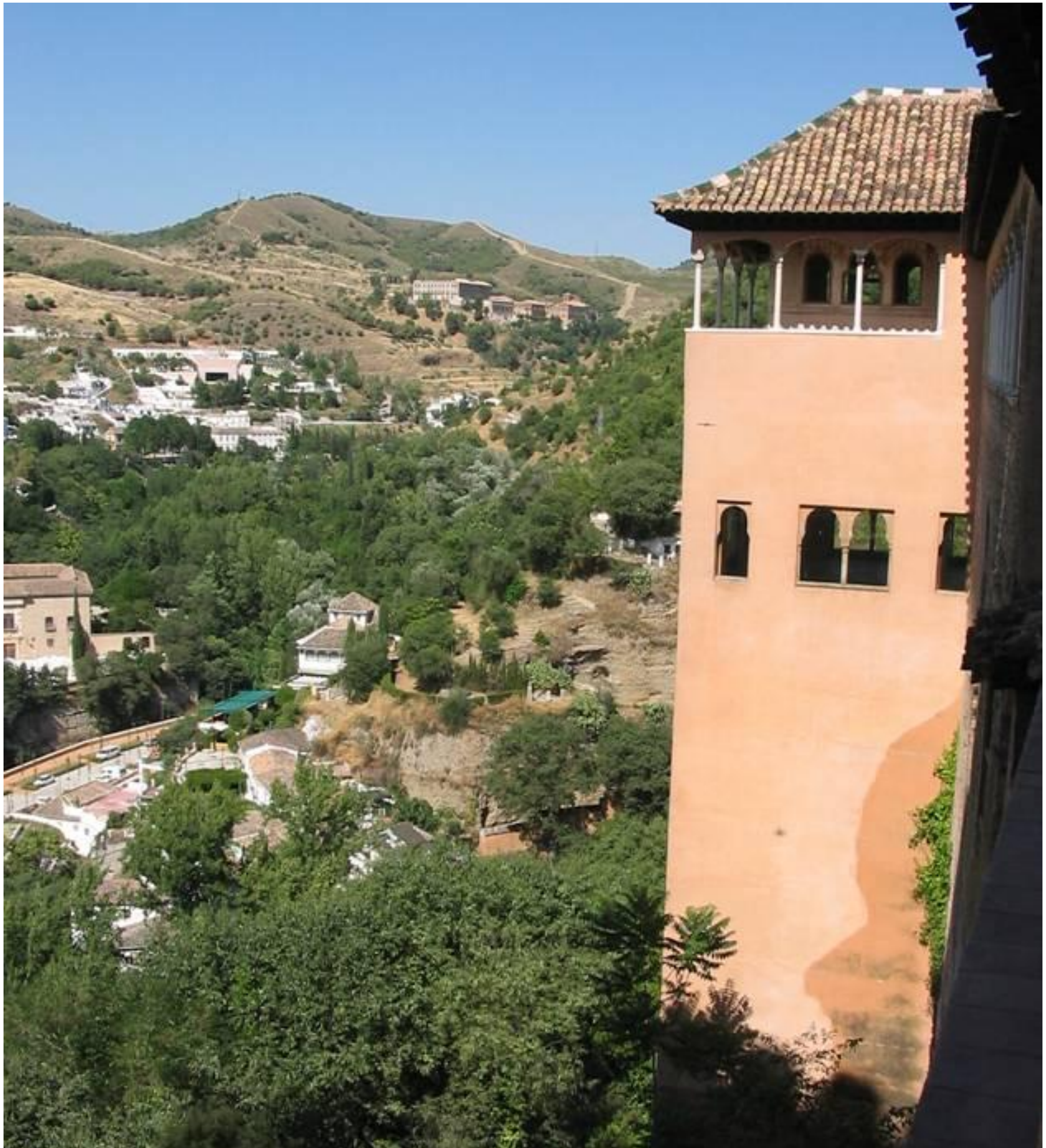


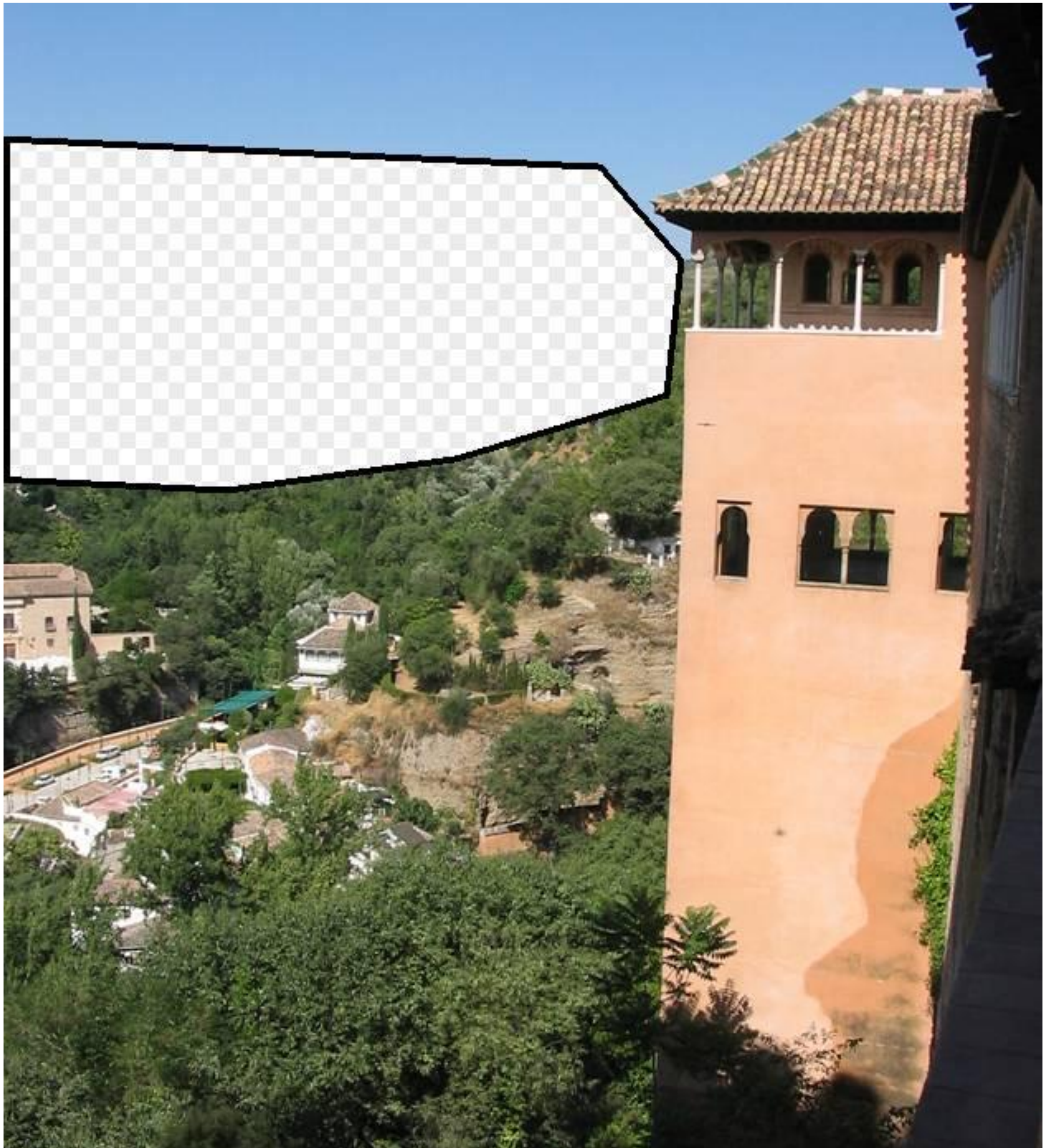
The graph cut cost





… 200 scene matches





Which is the original?

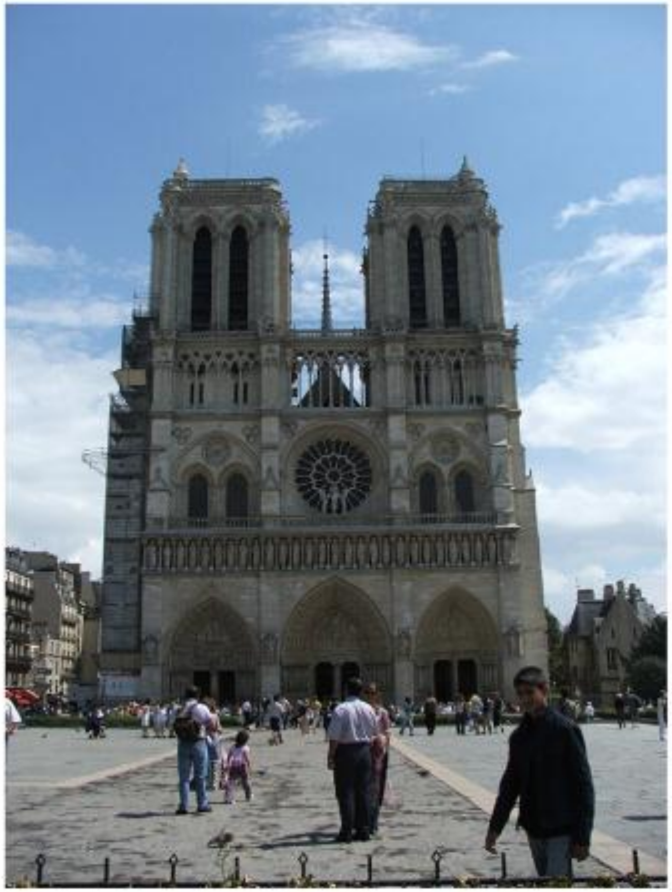
Scene Completion Result

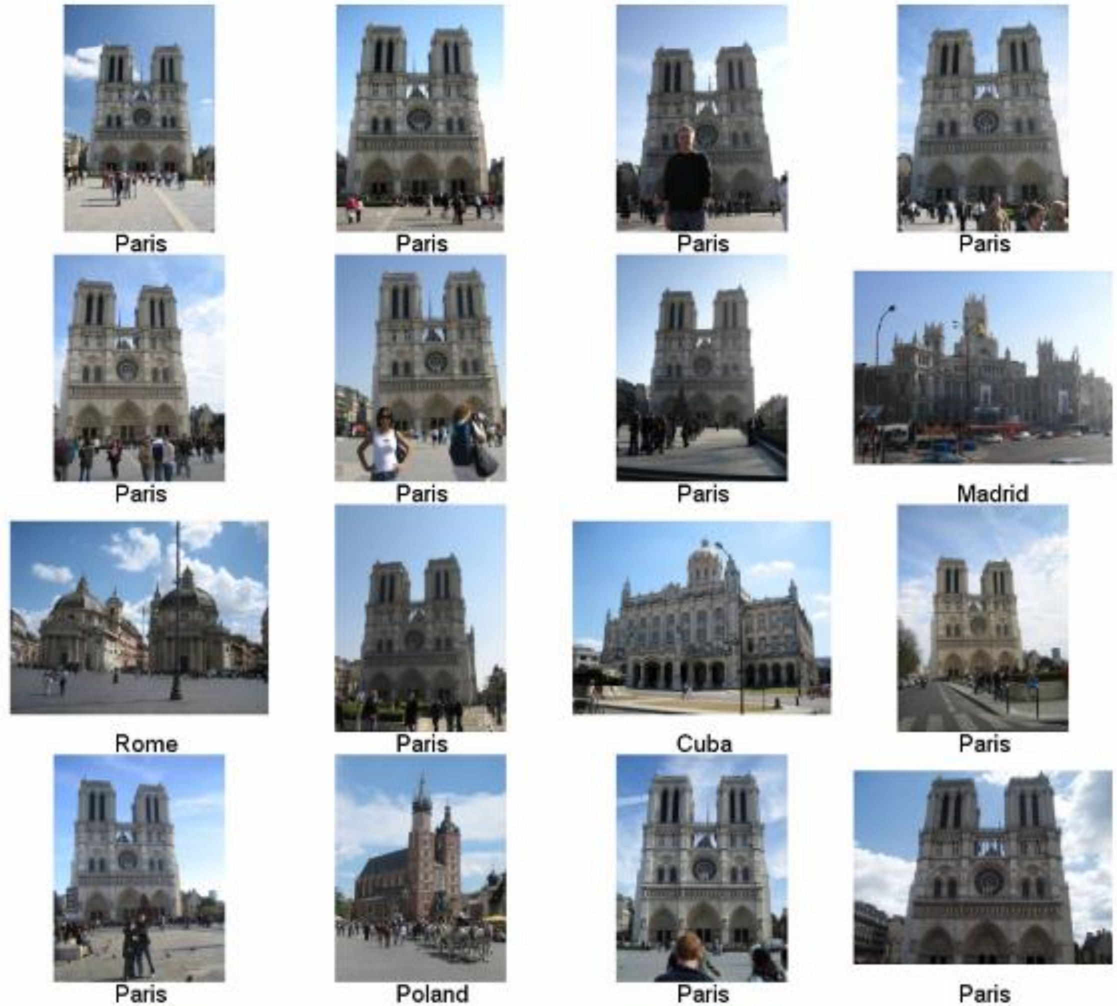
im2gps (Hays & Efros, CVPR 2008)

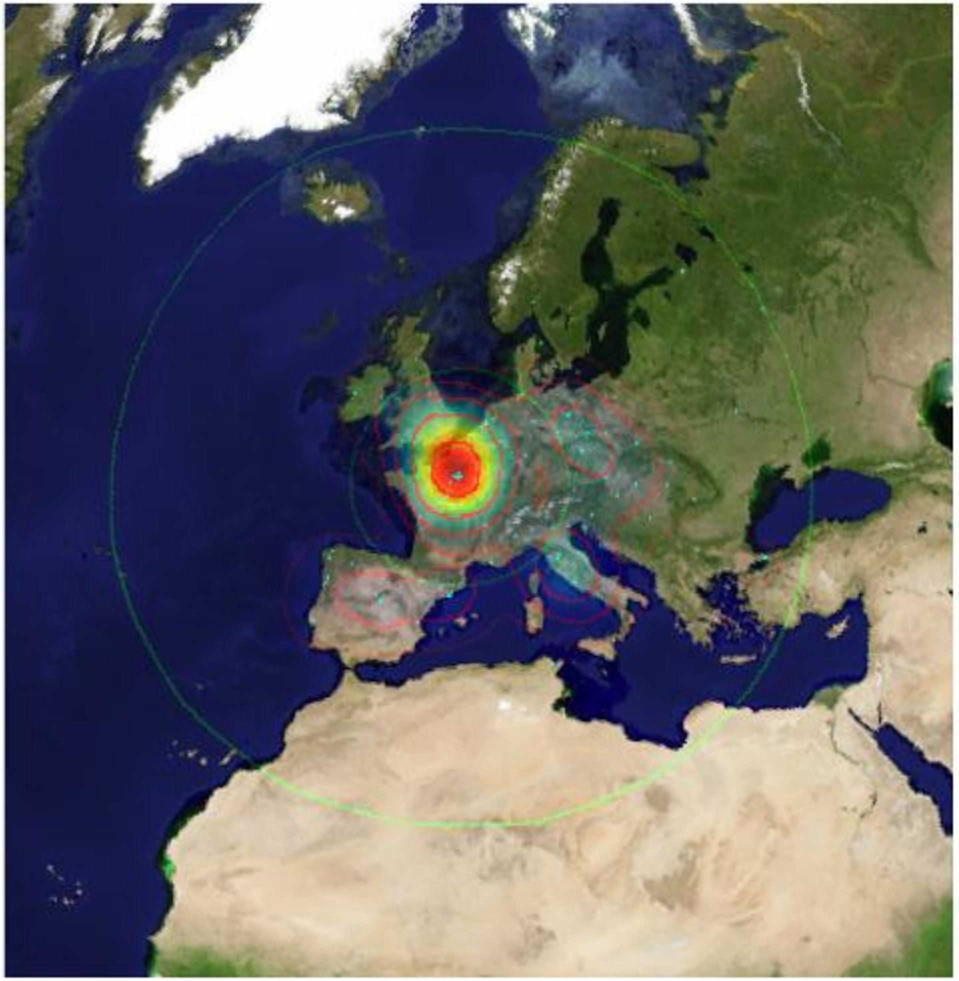
6 million geo-tagged Flickr images

http://graphics.cs.cmu.edu/projects/im2gps/

How much can an image tell about its geographic location?

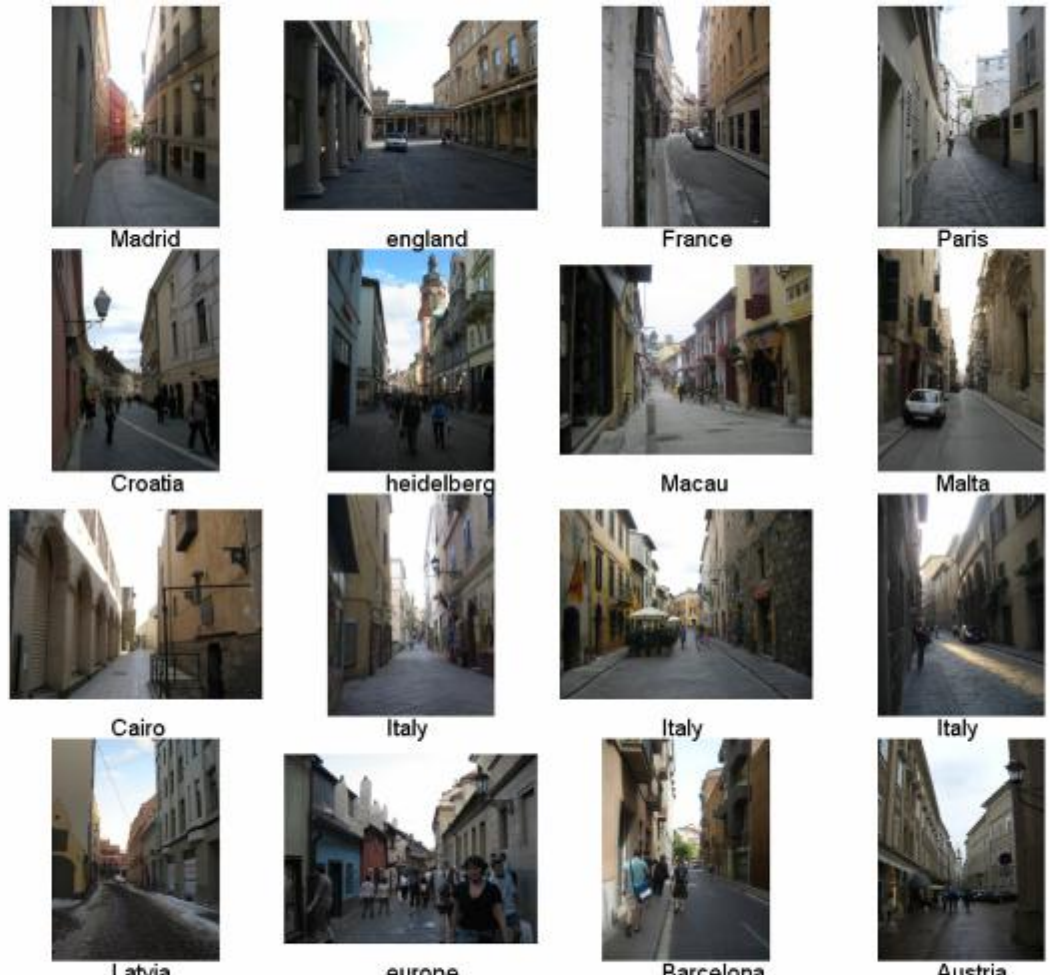



Paris
Paris
Paris
Paris
Paris
Paris
Paris
Madrid
Rome
Paris
Cuba
Paris
Paris
Poland
Paris
Paris

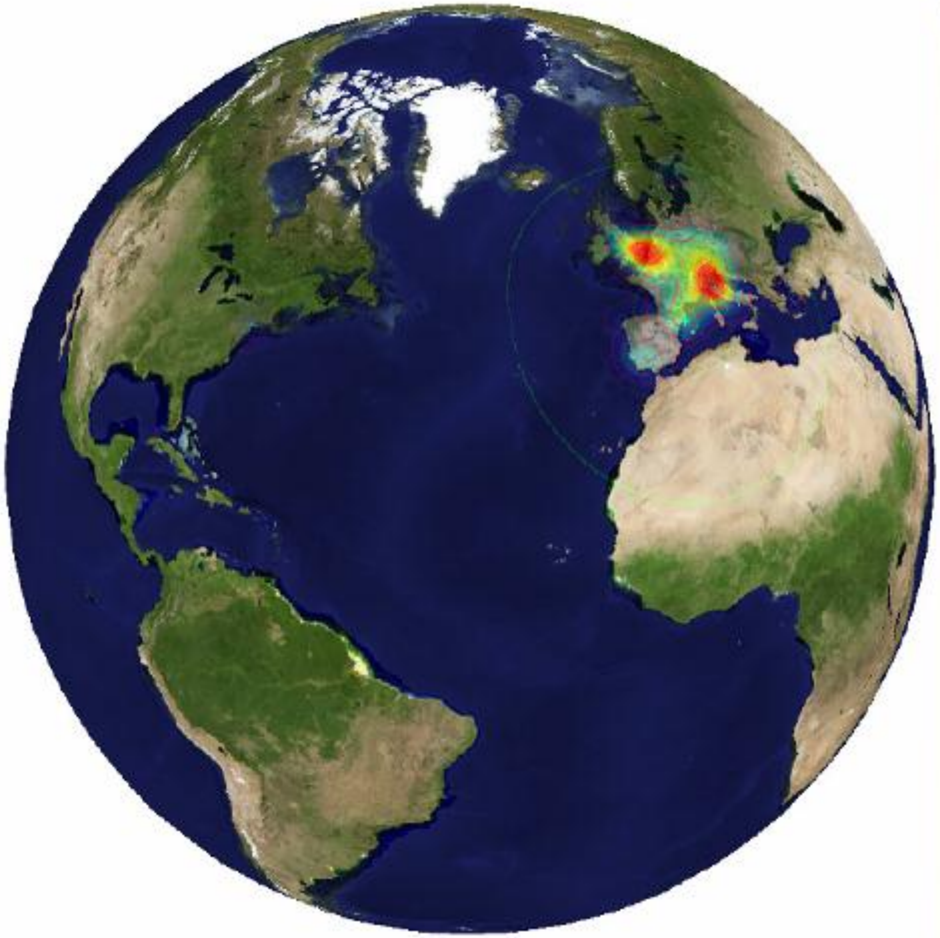



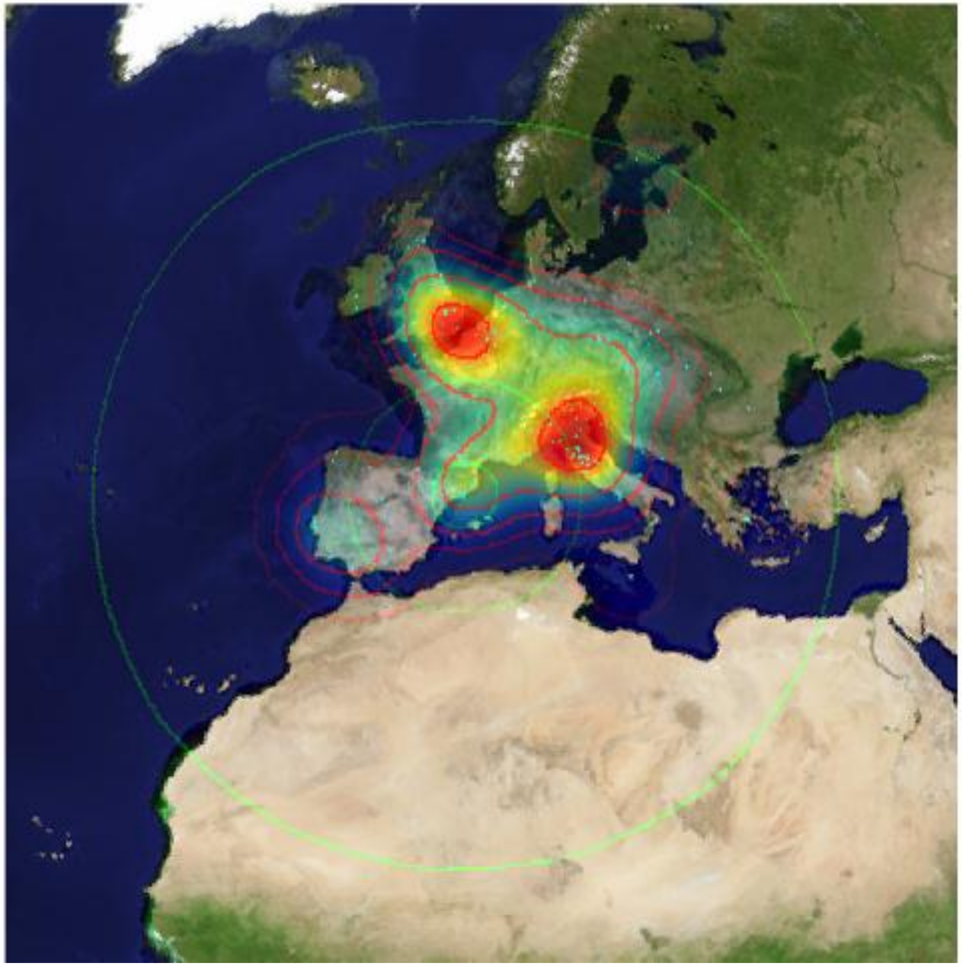
Im2gps

Example Scene Matches



Voting Scheme





im2gps


Philippines


Houston


Thailand


Houston


Maldives


Philippines


NewZealand


Bermuda


Palau


Mexico2


Brazil

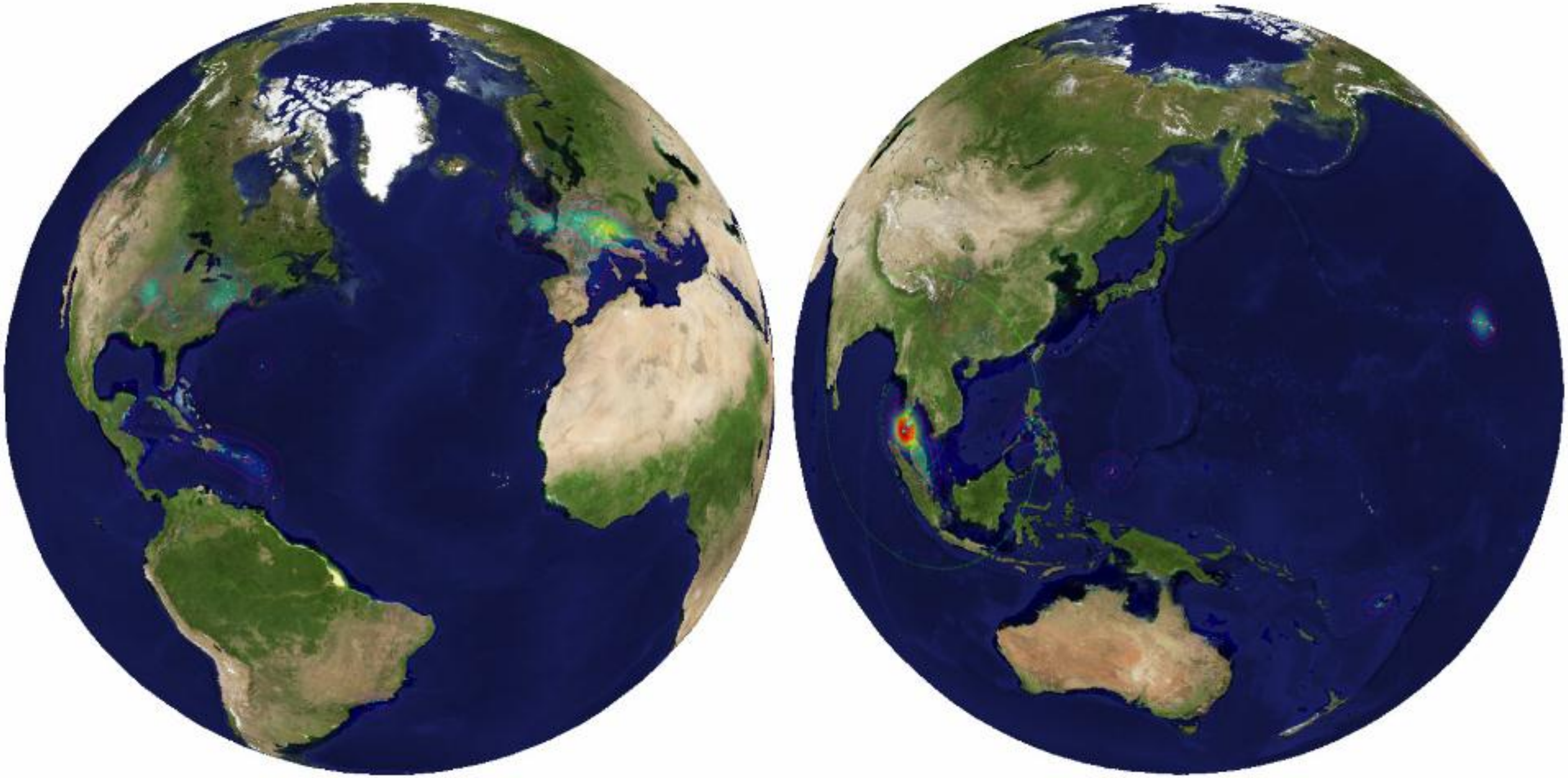

Mendoza


Brazil

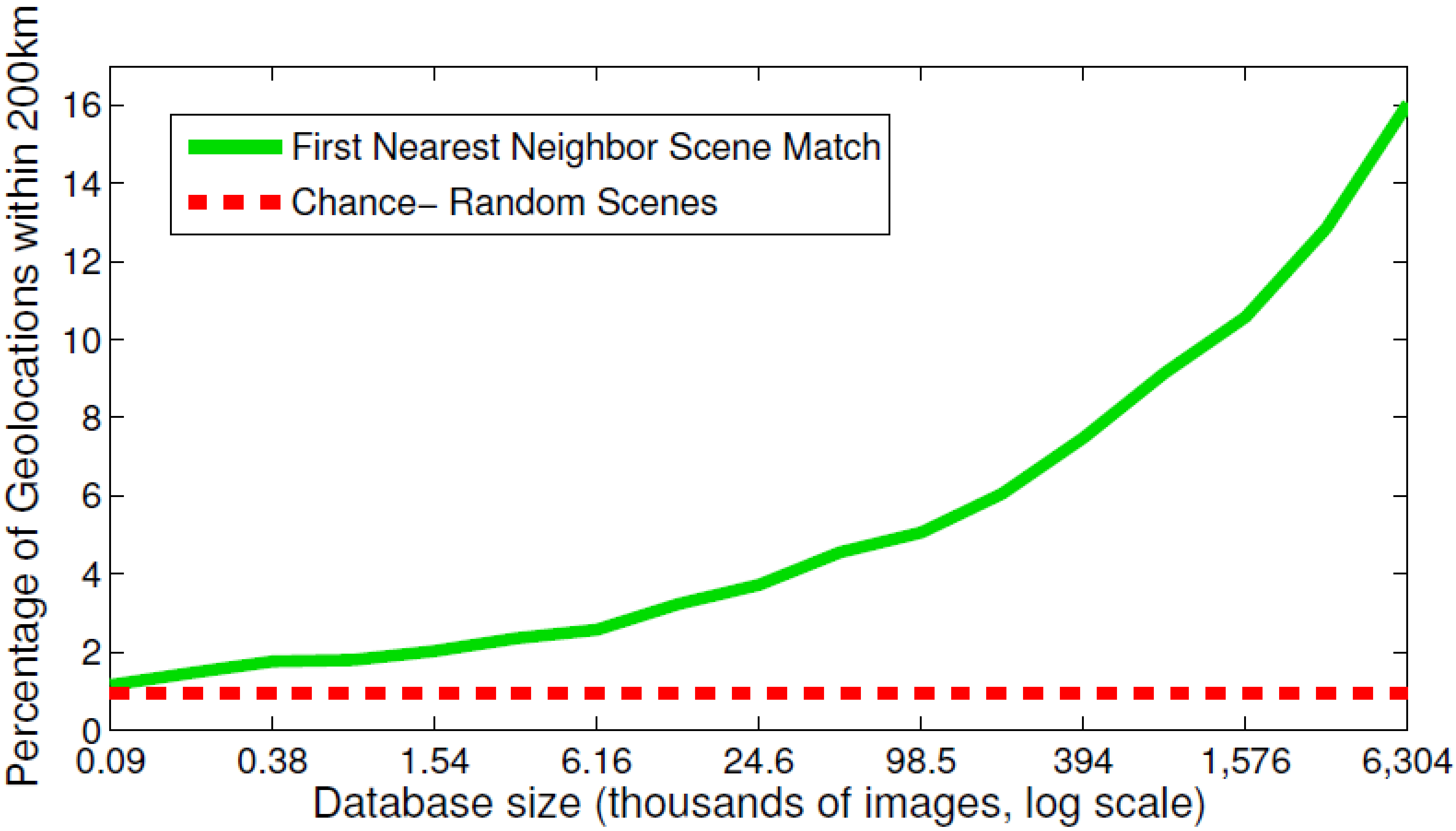

Thailand


Arkansas


Hawaii



Effect of Dataset Size



Population density ranking

High Predicted Density

Low Predicted Density

Where is This?

[Olga Vesselova, Vangelis Kalogerakis, Aaron Hertzmann, James Hays, Alexei A. Efros. Image Sequence Geolocation. ICCV'09]

Where is This?

Where are These?

15:14,
June 18^{th}, 2006

16:31,
June 18^{th}, 2006

Where are These?

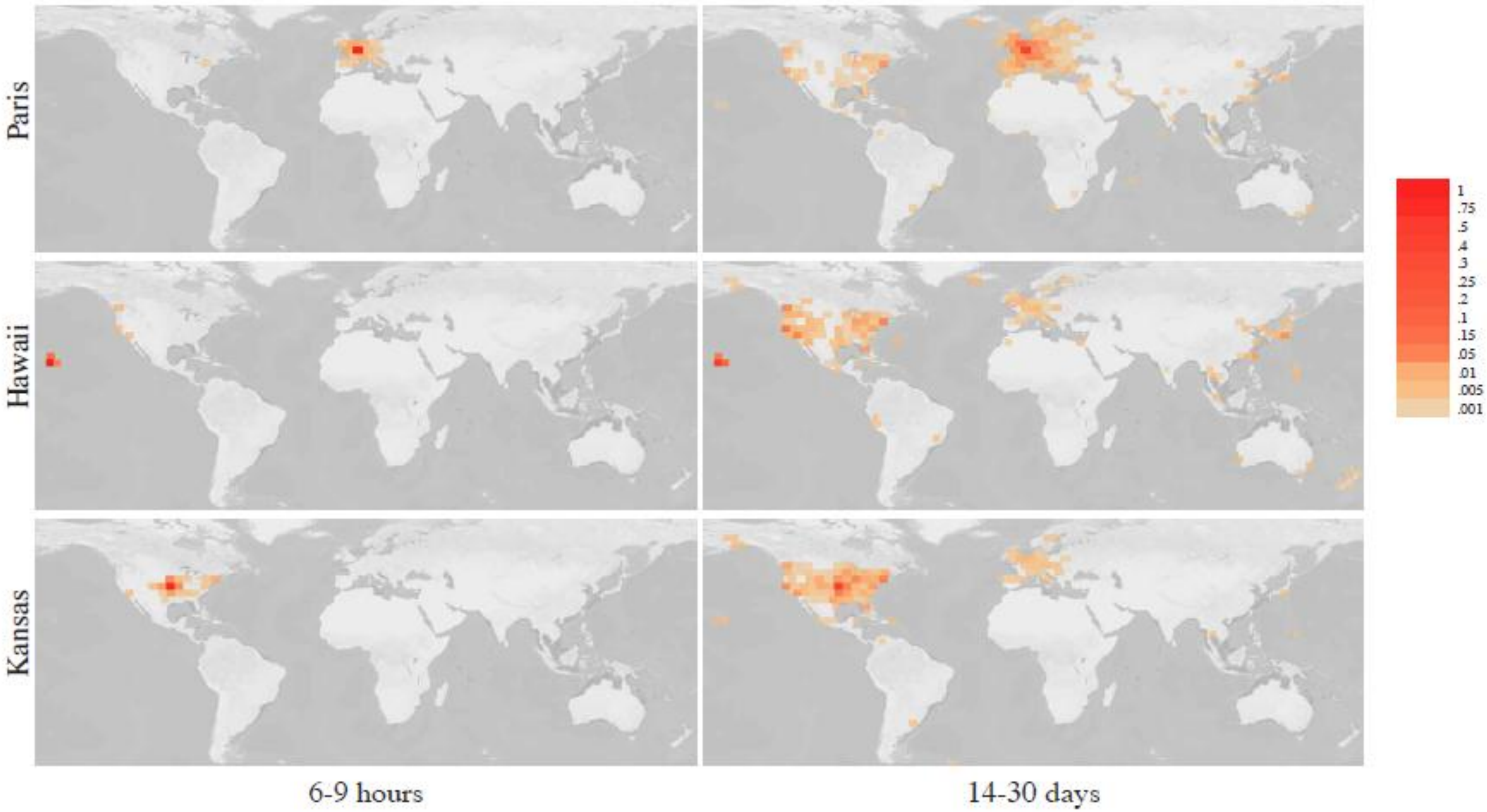
15:14,
June 18th, 2006

16:31,
June 18th, 2006

17:24,
June 19th, 2006

Results

- im2gps – 10% (geo-loc within 400 km)
- temporal im2gps – 56%



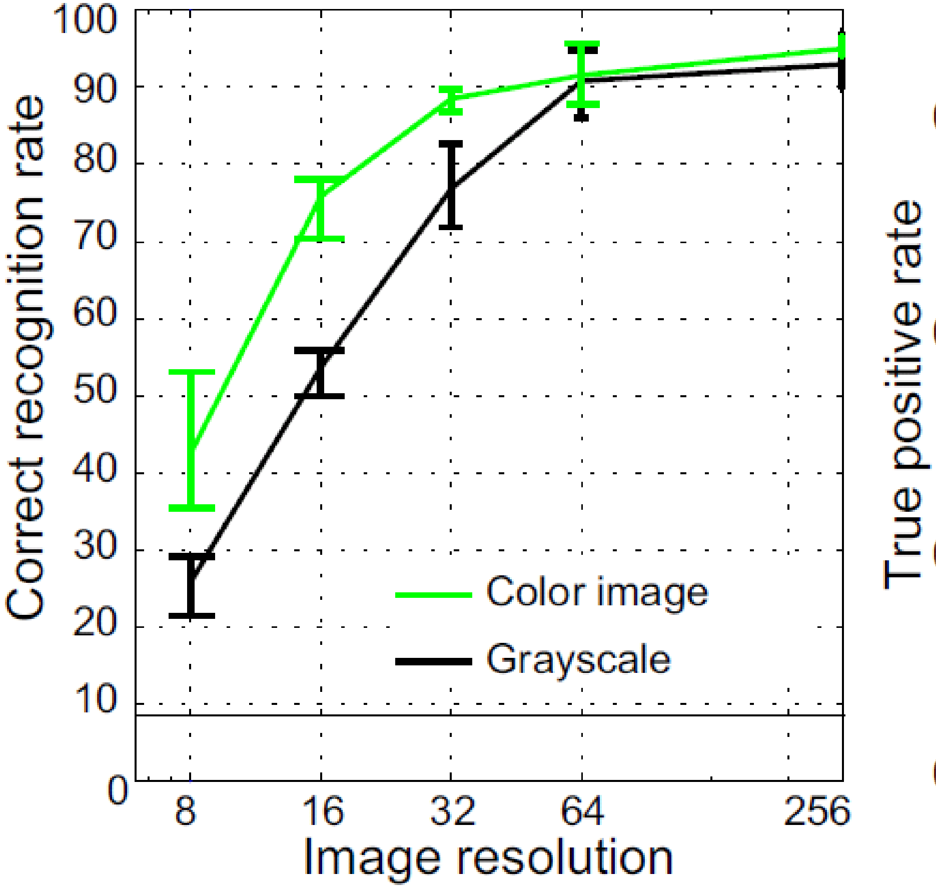
Tiny Images

80 million tiny images: a large dataset for non-parametric object and scene recognition
Antonio Torralba, Rob Fergus and William T. Freeman. PAMI 2008.

http://groups.csail.mit.edu/vision/TinyImages/

c) Segmentation of 32x32 images

Human Scene Recognition

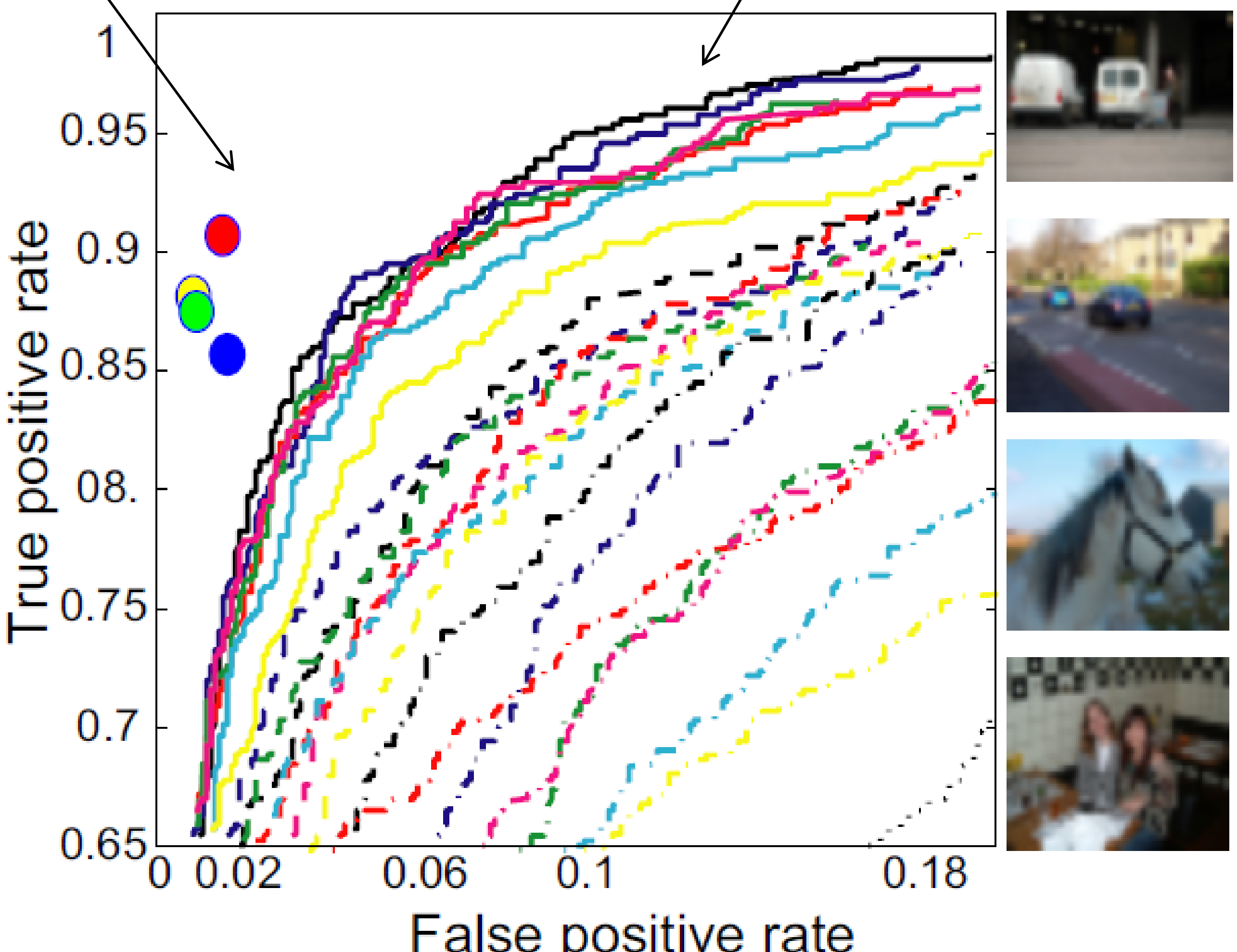


a) Scene recognition

Humans vs. Computers: Car-Image Classification

Humans for 32 pixel tall images

Various computer vision algorithms for full resolution images



Powers of 10

Number of images on my hard drive: 10^4

Number of images seen during my first 10 years: 10^8

(3 images/second * 60 * 60 * 16 * 365 * 10 = 630720000)

Number of images seen by all humanity: 10^{20}

106,456,367,669 humans[1] * 60 years * 3 images/second * 60 * 60 * 16 * 365 =

1 from http://www.prb.org/Articles/2002/HowManyPeopleHaveEverLivedonEarth.aspx

Number of photons in the universe: 10^{88}

Number of all 32x32 images: 10^{7373}

$256^{32*32*3} \sim 10^{7373}$

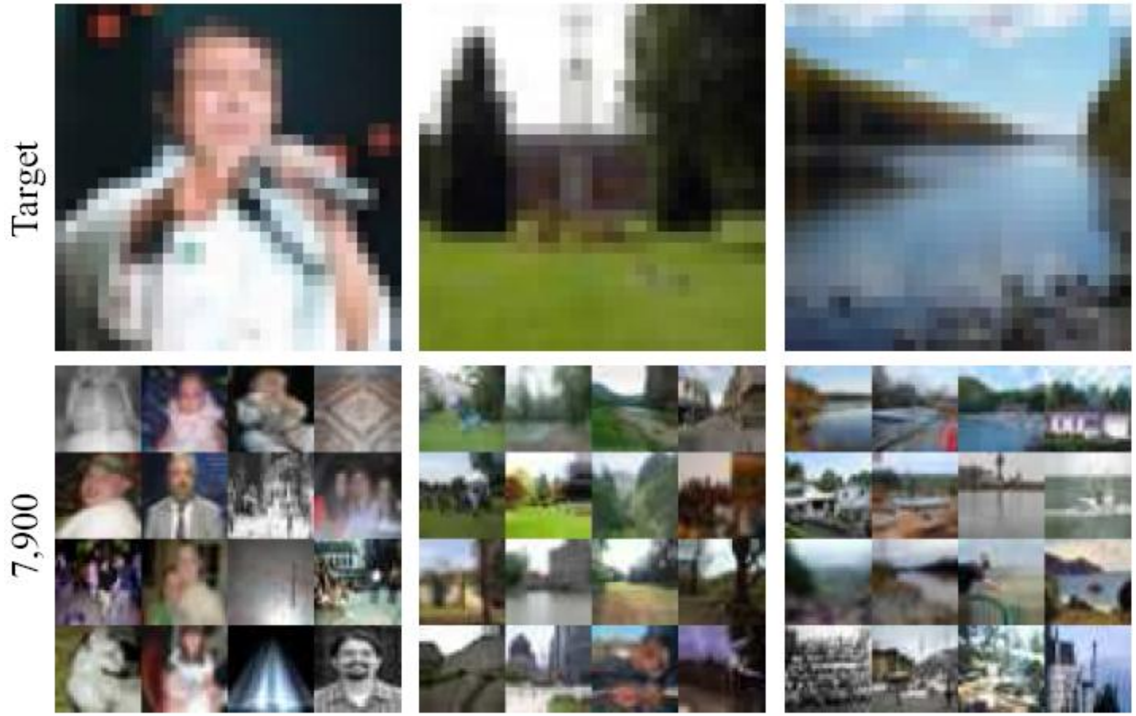
Scenes are unique

But not all scenes are so original

Lots

Of

Images

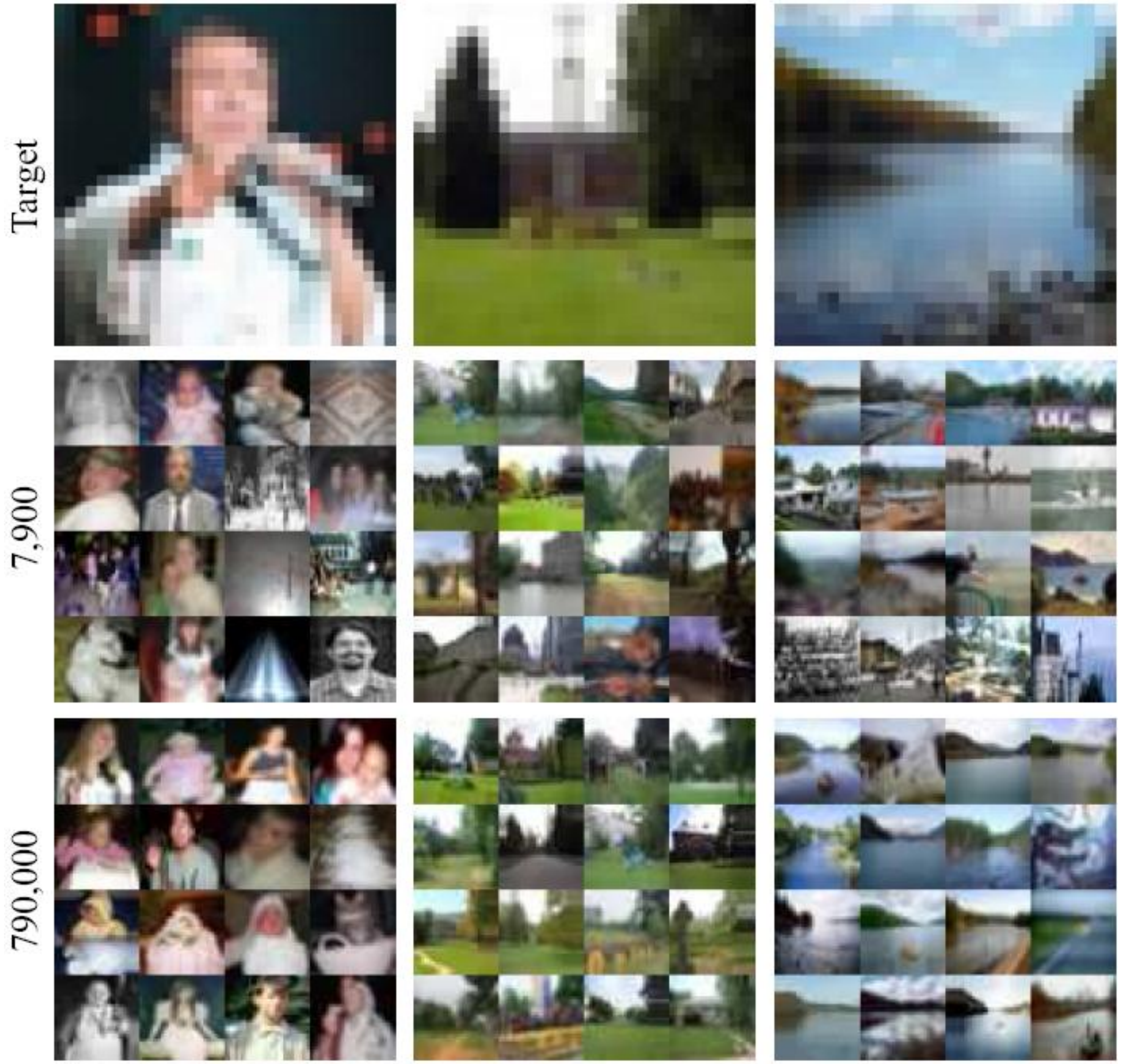


A. Torralba, R. Fergus, W.T.Freeman. PAMI 2008

Lots

Of

Images

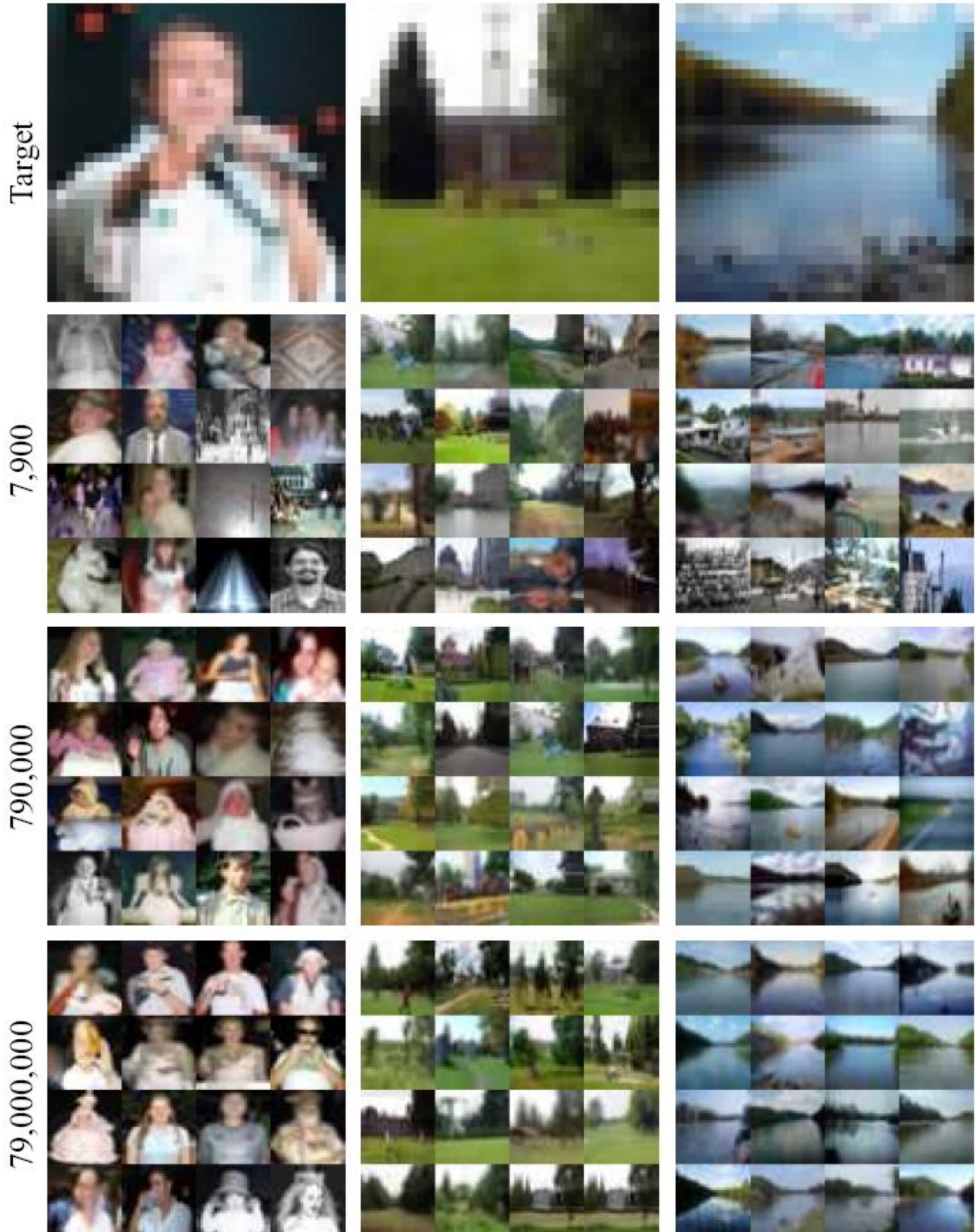


A. Torralba, R. Fergus, W.T.Freeman. PAMI 2008

Lots

Of

Images



Application: Automatic Colorization

Input

Color Transfer

Color Transfer

Matches (gray)

Matches (w/ color)

Avg Color of Match

Application: Automatic Colorization

Input

Color Transfer

Color Transfer

Matches (gray)

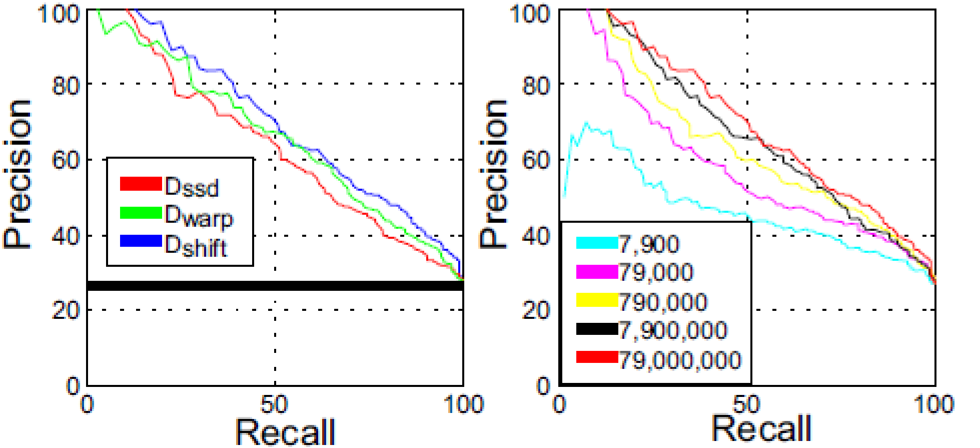
Matches (w/ color)

Avg Color of Match

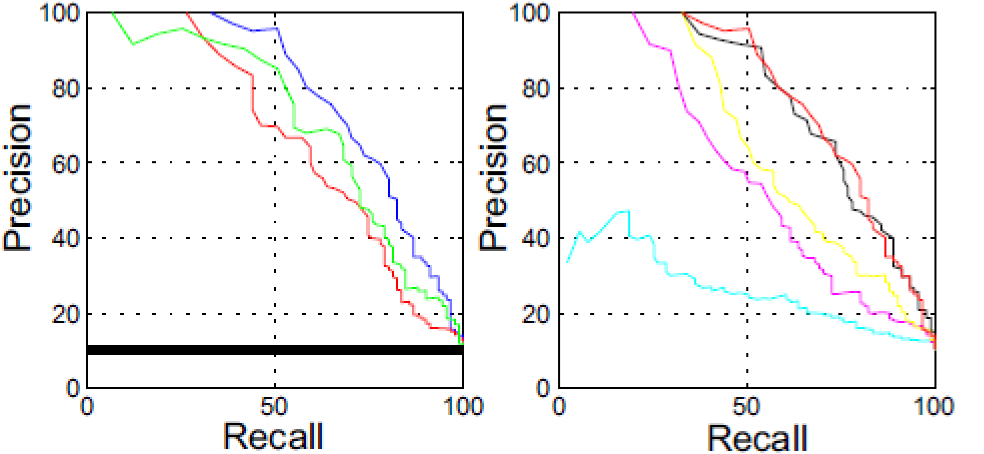
Application: Person Detection

80 million "tiny images" downloaded by keyword search.

80 nearest neighbors vote for image category.

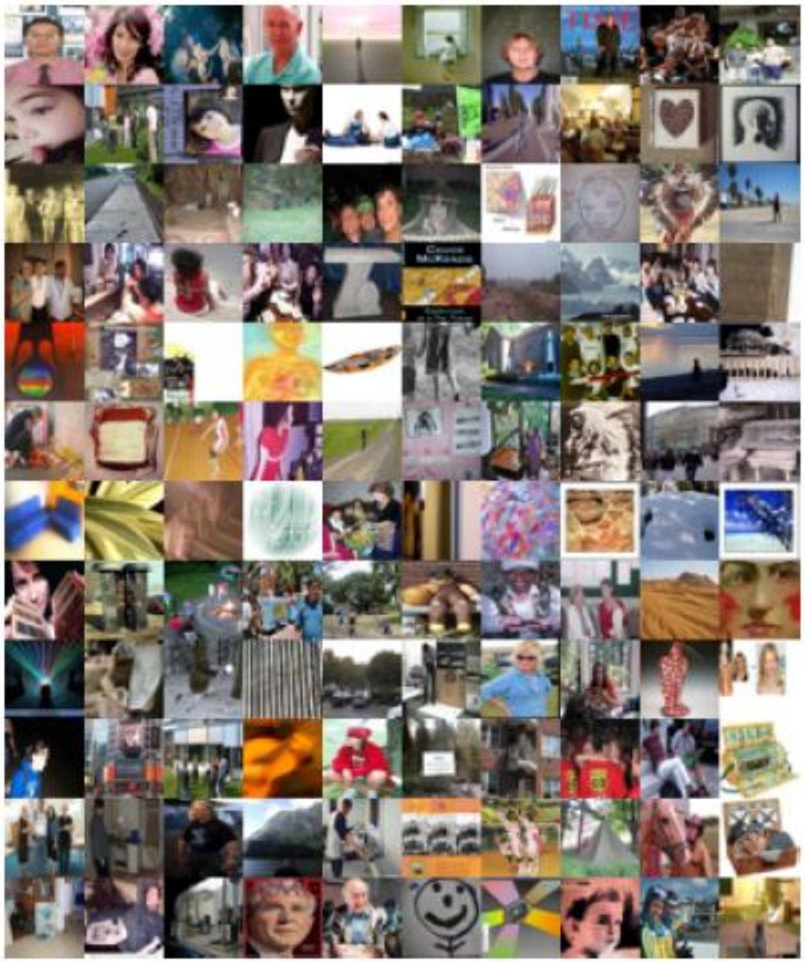


a) Person detection



b) Person detection (head size > 20%)

Re-ranking Altavista search for "person"



a) Altavista ranking

b) Sorted by the tiny images

Recognition by Association

Rather than categorizing objects, associate them with stored examples of objects and transfer the associated labels.

Malisiewicz and Efros (CVPR 2008)

Training procedure

- Learn a region similarity measure from hand-segmented objects in LabelMe

- Similarity features
  - Shape: region mask, pixel area, bounding box size
  - Texture: normalized texton histogram
  - Color: mean RGB, std RGB, color histogram
  - Position: coarse 8x8 image mask, coords of top/bottom pixels

Training procedure

- Learn a distance/similarity measure *for each region*
  - Minimize distance to K most similar examples from same category
  - Maximize distance to examples from other categories

distance weights

distance measures

$$\{\mathbf{w}^*, \boldsymbol{\alpha}^*\} = \underset{\mathbf{w}, \boldsymbol{\alpha}}{\operatorname{argmin}} f(\mathbf{w}, \boldsymbol{\alpha})$$

$$f(\mathbf{w}, \boldsymbol{\alpha}) = \sum_{i \in C} \alpha_i L(-\mathbf{w} \cdot \mathbf{d}_i) + \sum_{i \notin C} L(\mathbf{w} \cdot \mathbf{d}_i)$$

$$\mathbf{w} \geq 0, \ \alpha_j \in \{0, 1\}$$

$$\textstyle\sum_j \alpha_j = K$$

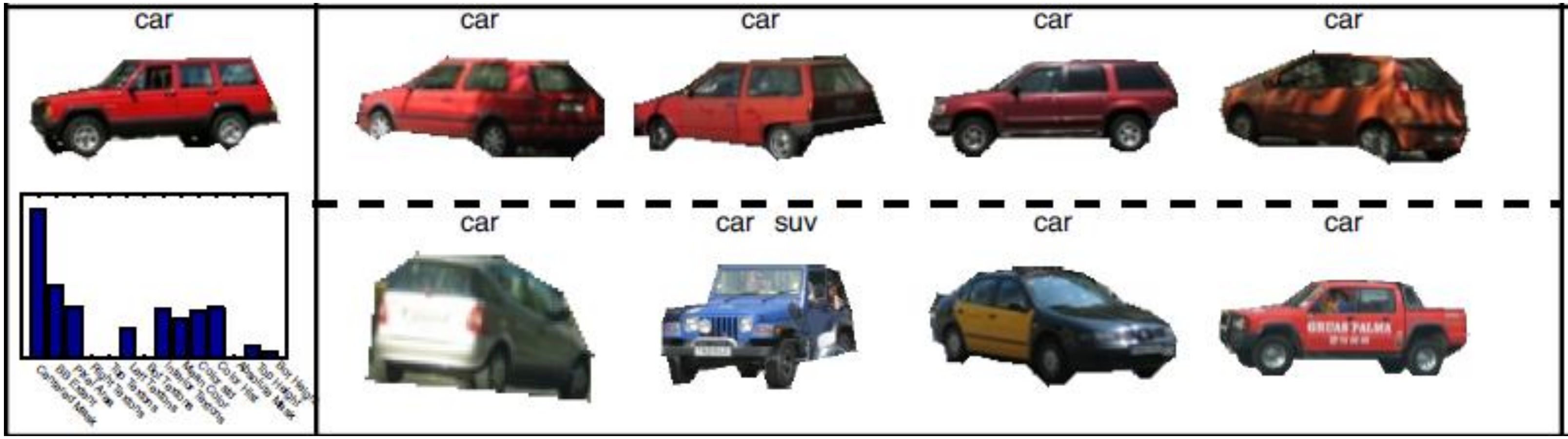
Set to 1 for K nearest examples

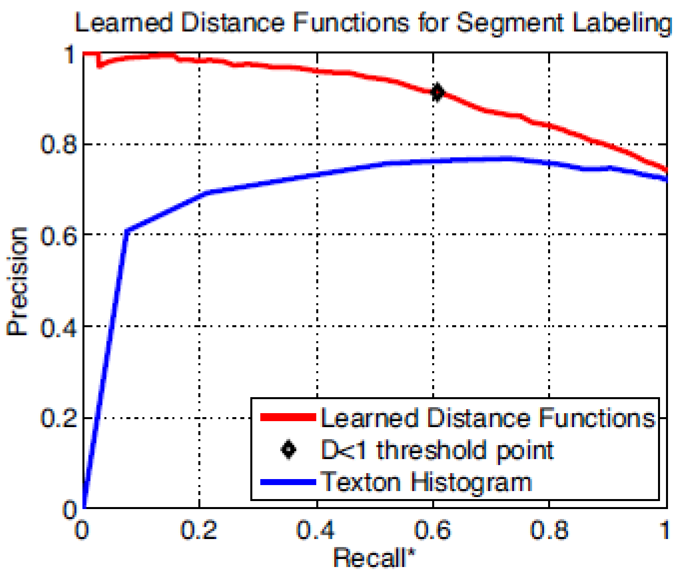
Hinge Loss

Learned Similarity Measure

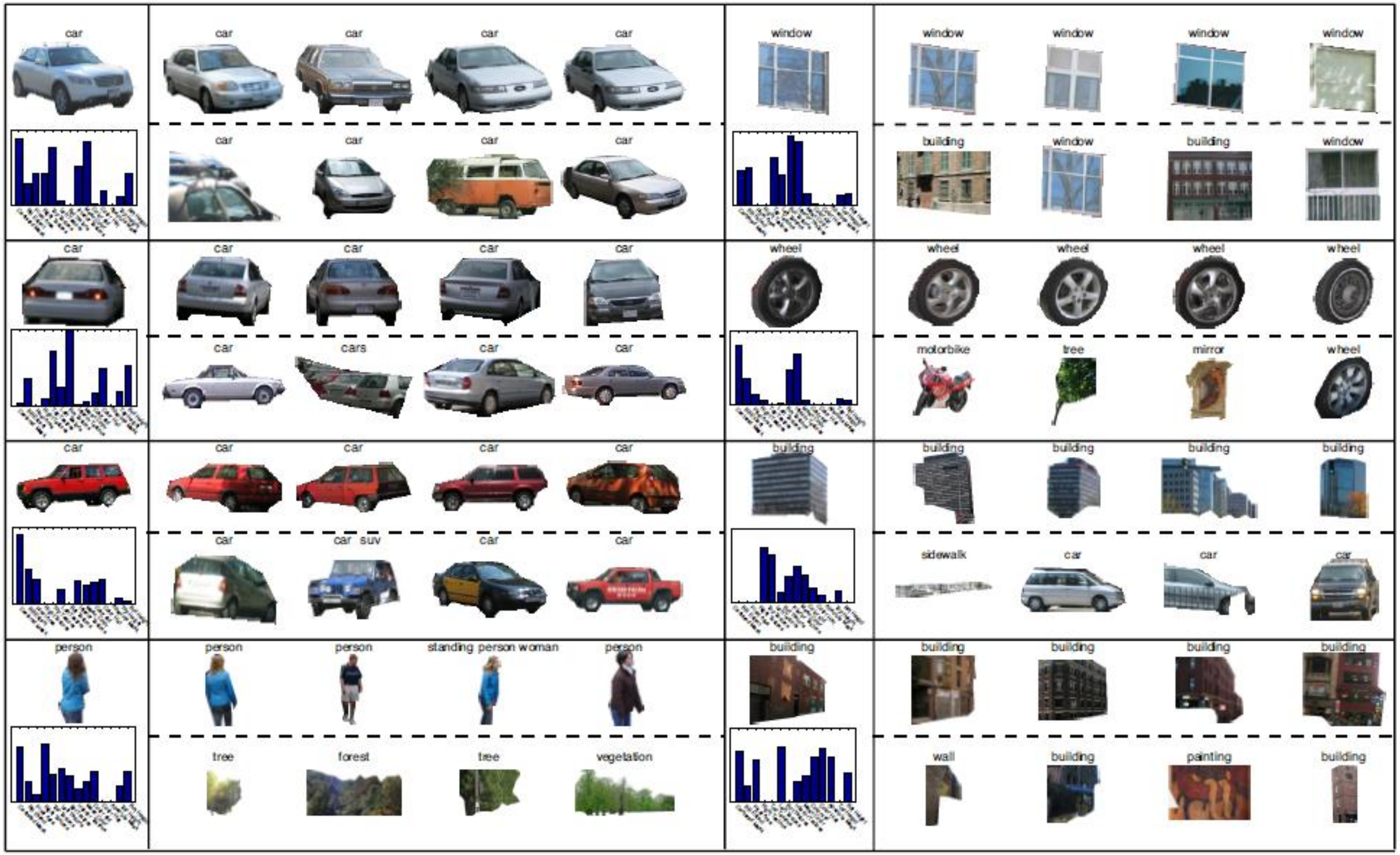
Learned Distance

Texton Distance



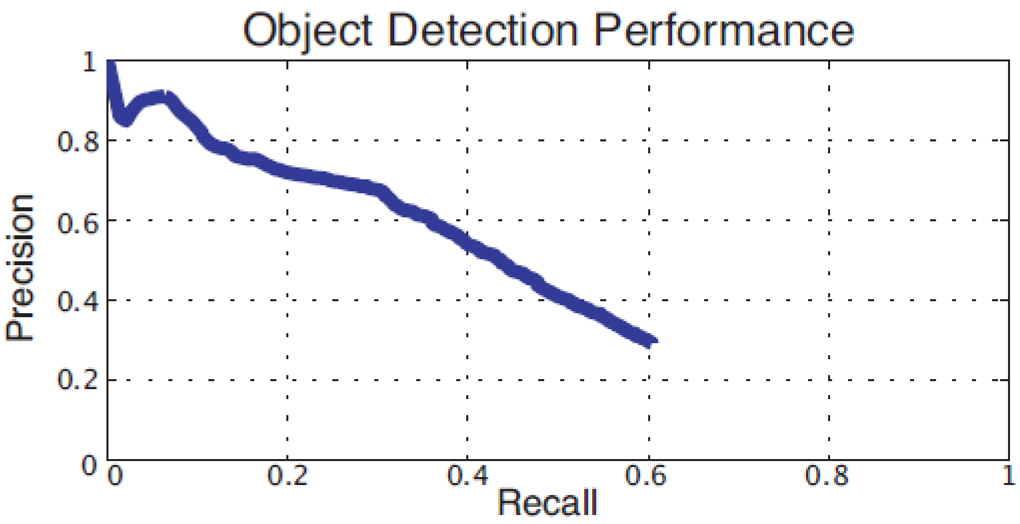


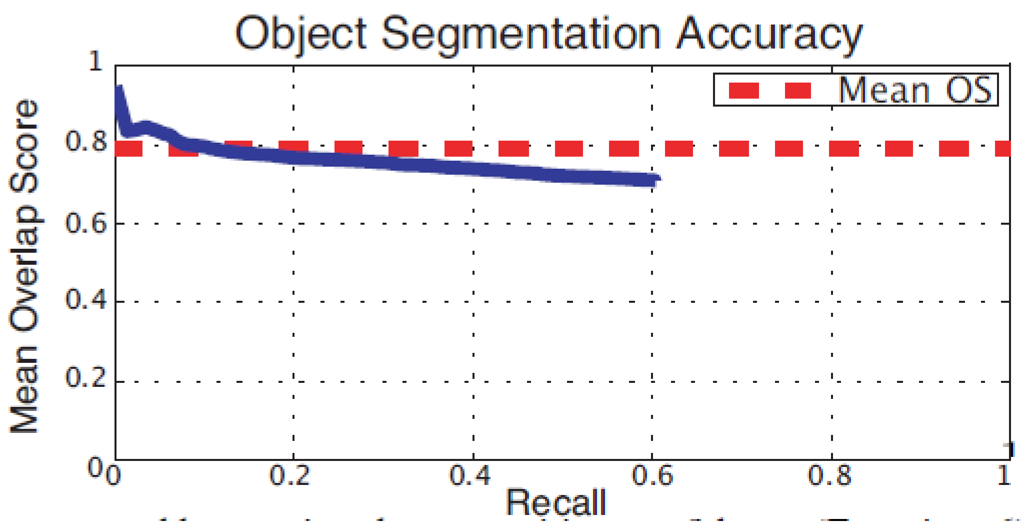
Learned Similarity Measure



Testing procedure

- Create multiple segmentations (MeanShift + Ncuts)
- Find similar object regions in training set; each votes for the object label
- What about bad segments?
  - Most of the time, they don’t match any objects in the training set
  - Consider only associations with distance < 1


Object Detection Performance
Precision
Recall
0
0.2
0.4
0.6
0.8
1


Object Segmentation Accuracy
Mean Overlap Score
Recall
Mean OS
0
0.2
0.4
0.6
0.8
1

Automatic Parses

Summary

- With billions of images on the web, it’s often possible to find a close nearest neighbor
- In such cases, we can shortcut hard problems by “looking up” the answer, stealing the labels from our nearest neighbor
- For example, simple (or learned) associations can be used to synthesize background regions, colorize, or recognize objects

Next class

- Summary and wrap-up
  - Short summary of computer vision
  - Important open problems

- Feedback (important!)
  - Short custom form that goes directly to me
  - ICES forms that go to department, then to me