Stanford University

Weather Understanding

Cewu Lu (卢策吾)

Research Fellow@ Stanford University

About Me

Stanford
Artificial Intelligence Laboratory

Research Fellow

Stanford University Computer Science
Artificial Intelligence Laboratory

Weather Understanding

- Weather affects our daily life.
- Camera is cheap weather monitor.

Smart Grid (国家智能电网)

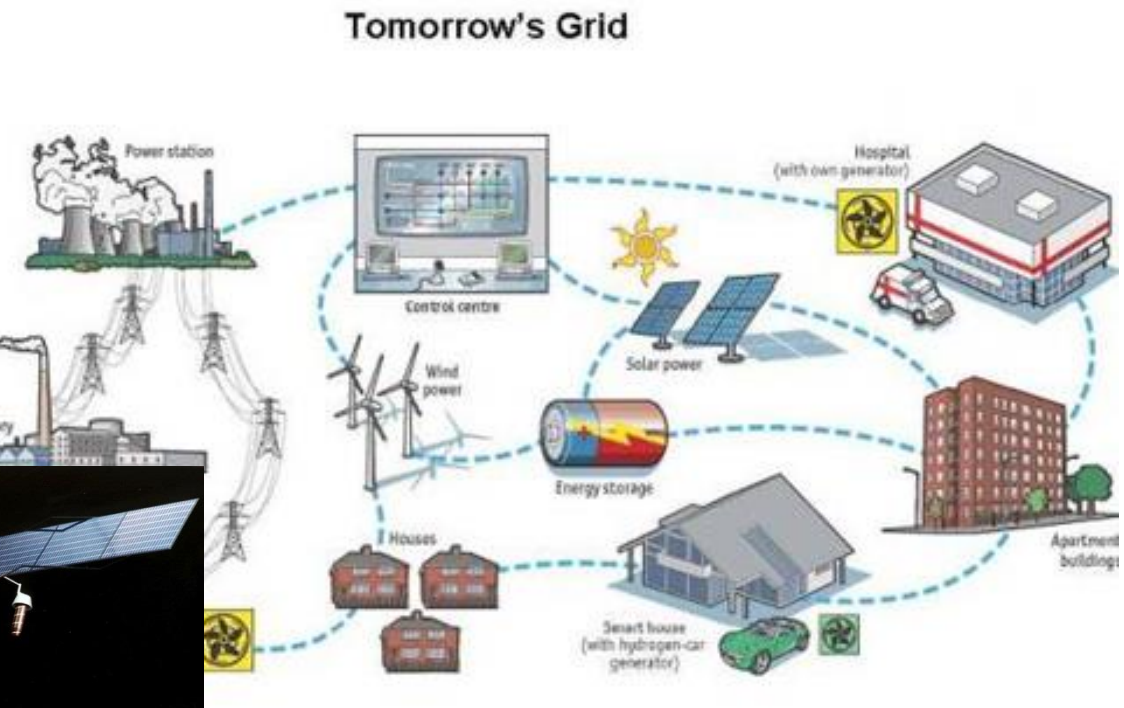
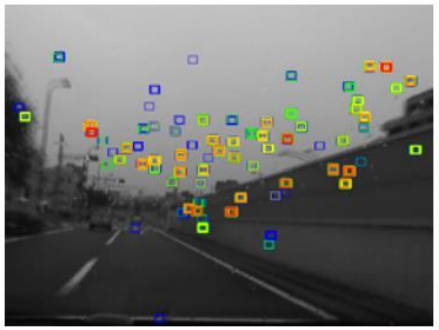


Photo is cheap and real-time

Satellite is time-delay!

Driving Assistance

(a) Input image



(b) Detection result

X. Yan, Y. Luo, and X. Zheng.
Weather recognition based on images captured by vision system in vehicle.

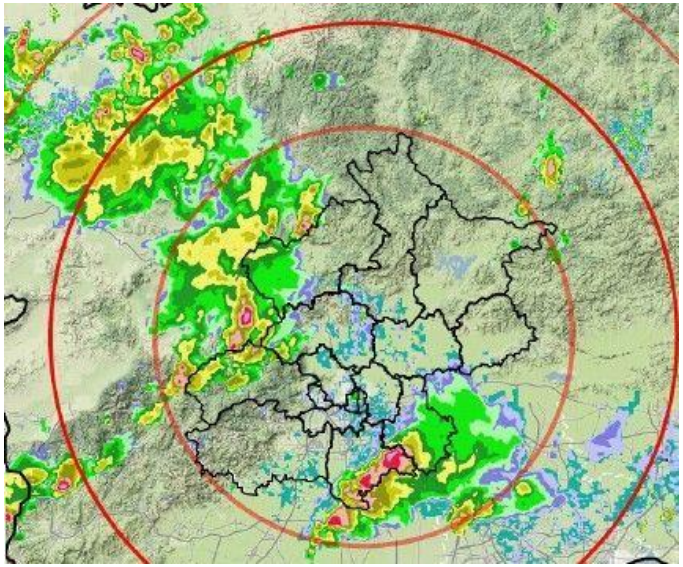
Weather Monitor

- In big data era: image is everywhere and anytime!

Motivation: weather real-time monitor

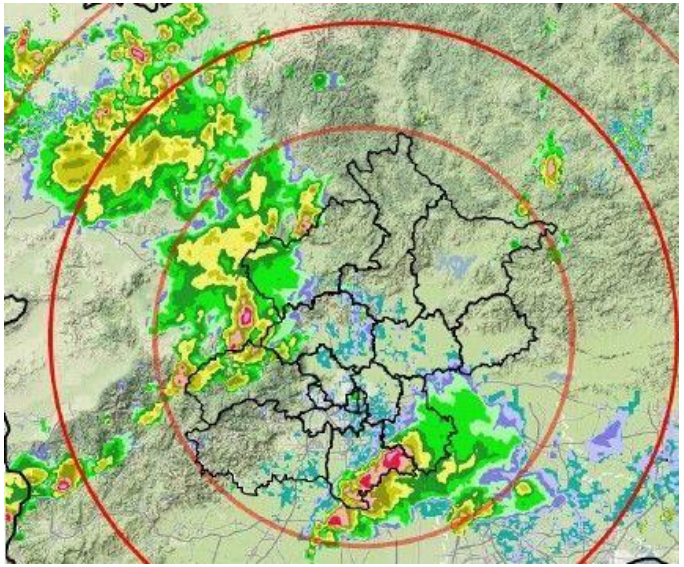
Weather Monitor

- Real-time
- Geometry dense



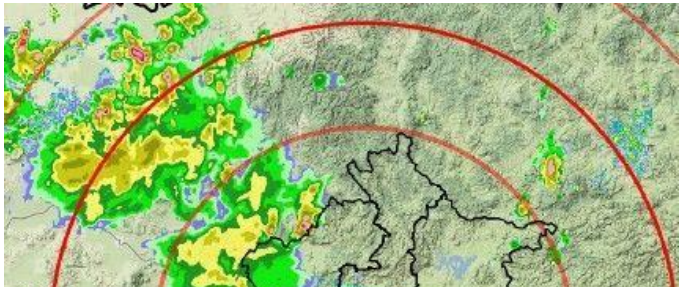
Weather Monitor

- Real-time
- Geometry dense



Smog visibility monitor (雾霾监控)

Weather Monitor



- Real-time

环境监测仪器设备的采购力度，为行业带来了拉动力量。此外，目前环境监测仪器设备的毛利率较高，市场前景广阔，也使行业发展加速。

通过环境在线监测仪器能够及时、准确、全面对环境质量和污染源现状及发展趋势进行实时监测，为环境管理、环境规划和污染防治提供依据。根据国家统计局公布的数字，环境监测仪器行业2012年行业总收入规模达140.92亿元，2004年至今复合增长率高达35.64%，其增长速度明显高于仪器领域的其他子行业。十二五期间，随着国家对环境监测行业的政策支持和资金投入，我国环境监测仪器市场仍将会保持着快速增长。按照环保十二五规划，环境监测十二五期间总投资需求将达1000亿元。

国家政策助力行业发展

近年来国家出台的环保、节能减排政策为环保监测仪表行业的发展也送来了政策春风。2012年4月环保部发布的《国家环境监测十二五规划》提出，

http://yiqiso.lofter.com/post/3204b3_e250fa

Weather Understanding

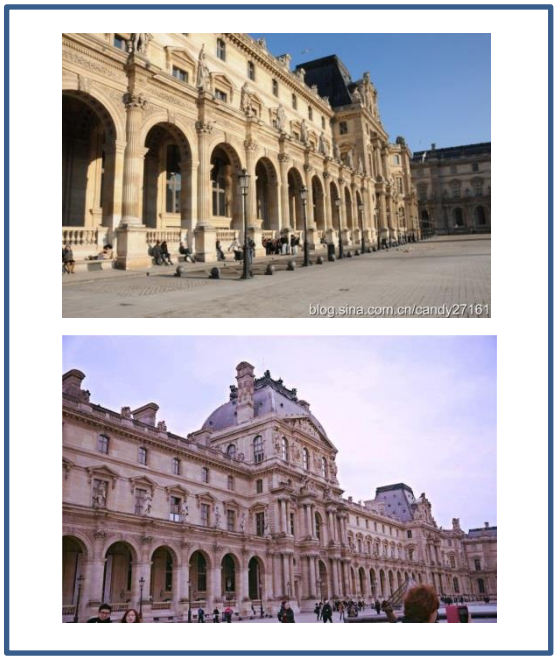
- Industry value (经济价值)
  天气对人的生活，户外机器人很重要！
  图像获取很便宜！

- Academic value(学术价值)
  人能理解天气，但计算机能吗？

Why is it difficult?

- Scene Understanding + illumination Understanding + ??

纠结在一起

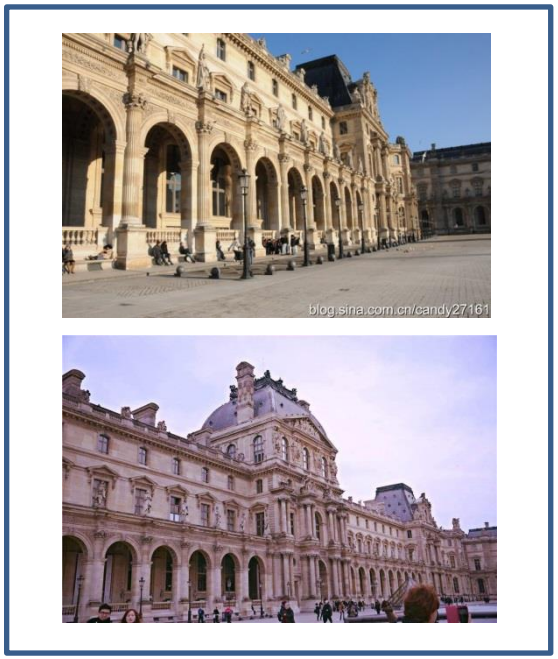


Training data

Why is it difficult?

- Scene Understanding + illumination Understanding + ??

纠结在一起



Training data

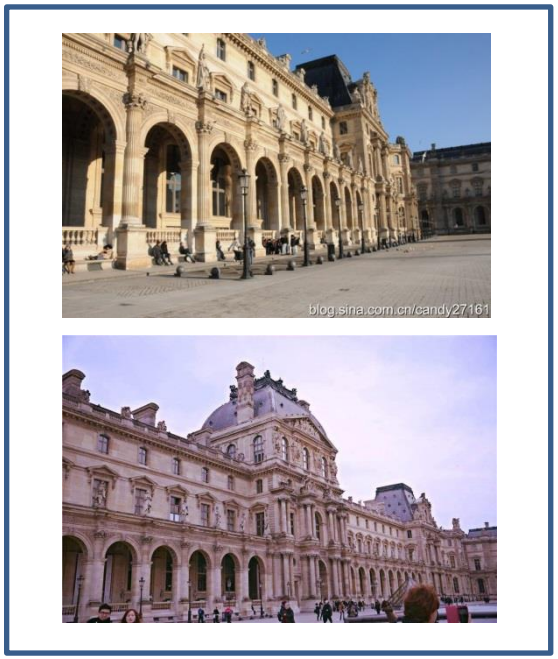
Cloudy

Fix scene

Why is it difficult?

- Scene Understanding + illumination Understanding + ??

纠结在一起



Training data

Why is it difficult?

- Scene Understanding + illumination Understanding + ??

纠结在一起

Rainy day

Why is it difficult?

- Scene Understanding + illumination Understanding + ??

Traditional scene understanding considers structure pattern only!

Weather Understanding

- Two-class weather classification [CVPR 2014]
- Visibility **(能见度)** Estimation submitted to [PAMI 2015]

Two-class Weather Classification

Cewu Lu Di Lin Jiaya Jia Chi-Keung Tang

Abstract

Given a single outdoor image this paper proposes a collaborative learning approach for labeling the image as either sunny or cloudy. Never adequately addressed, this two-class labeling problem is by no means trivial given the great variety of outdoor images. Our weather feature combines everyday weather cues after properly encoding them into feature vectors. These encoded cues then work collaboratively in synergy under a unified optimization framework that is aware of the presence (or absence) of a given weather cue during learning and classification. Extensive experiments and comparisons are performed to verify our method. The other contribution consists of a new weather image dataset consisting of 10K sunny and cloudy images which is freely available with the executable of our implementation.

Downloads

"Two-class Weather Classification"
Cewu Lu, Di Lin, Jiaya Jia, Chi-Keung Tang
IEEE Conference on Computer Vision and Pattern Recognition (***CVPR***), 2014

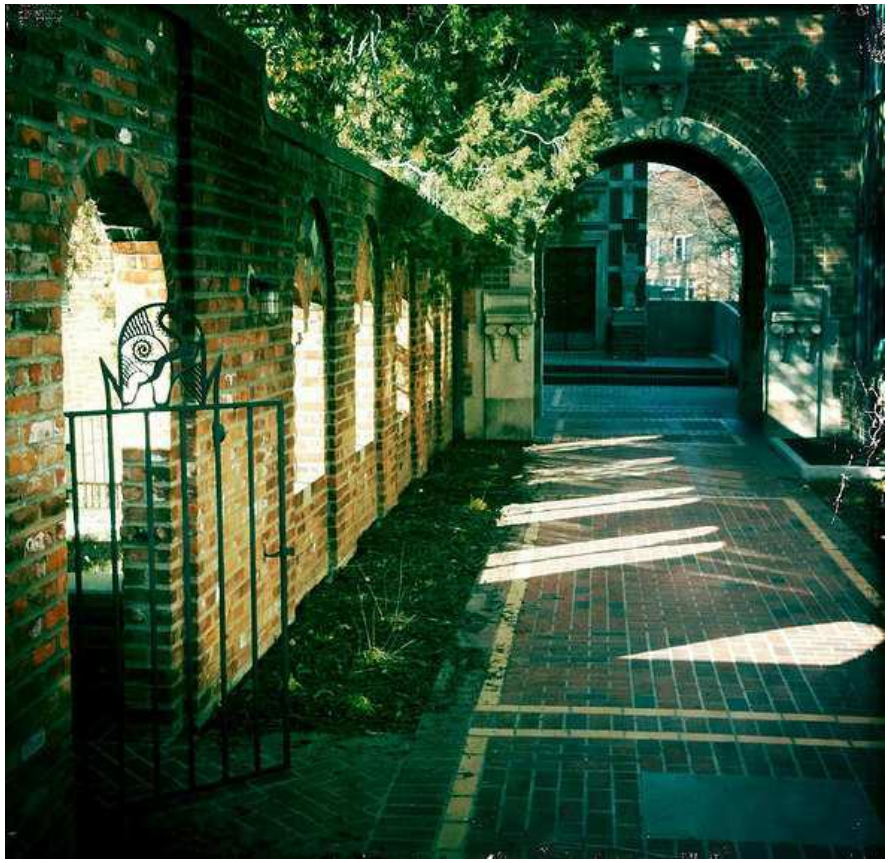
[Paper (pdf, 4MB)]

[Matlab Executable (real-time classification)]

[Sky Detector]

Two-Class Weather Classification

Sunny or Cloudy?

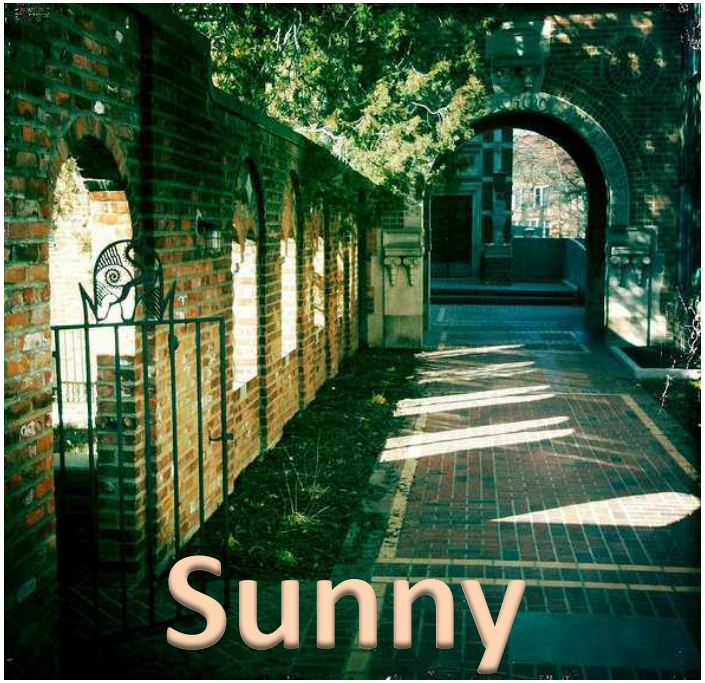


mean lightness 32.41

Sunny or Cloudy?

mean lightness 58.23

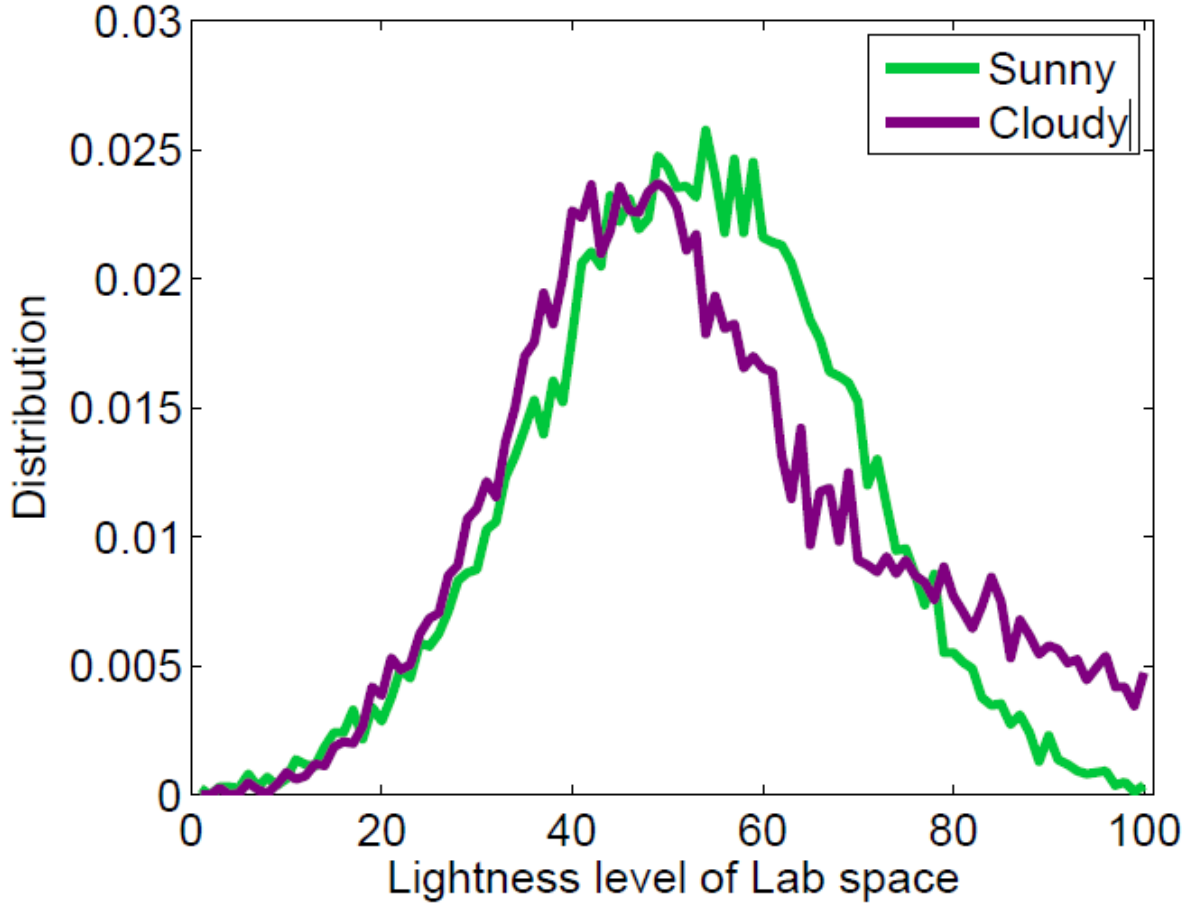
Sunny or Cloudy?



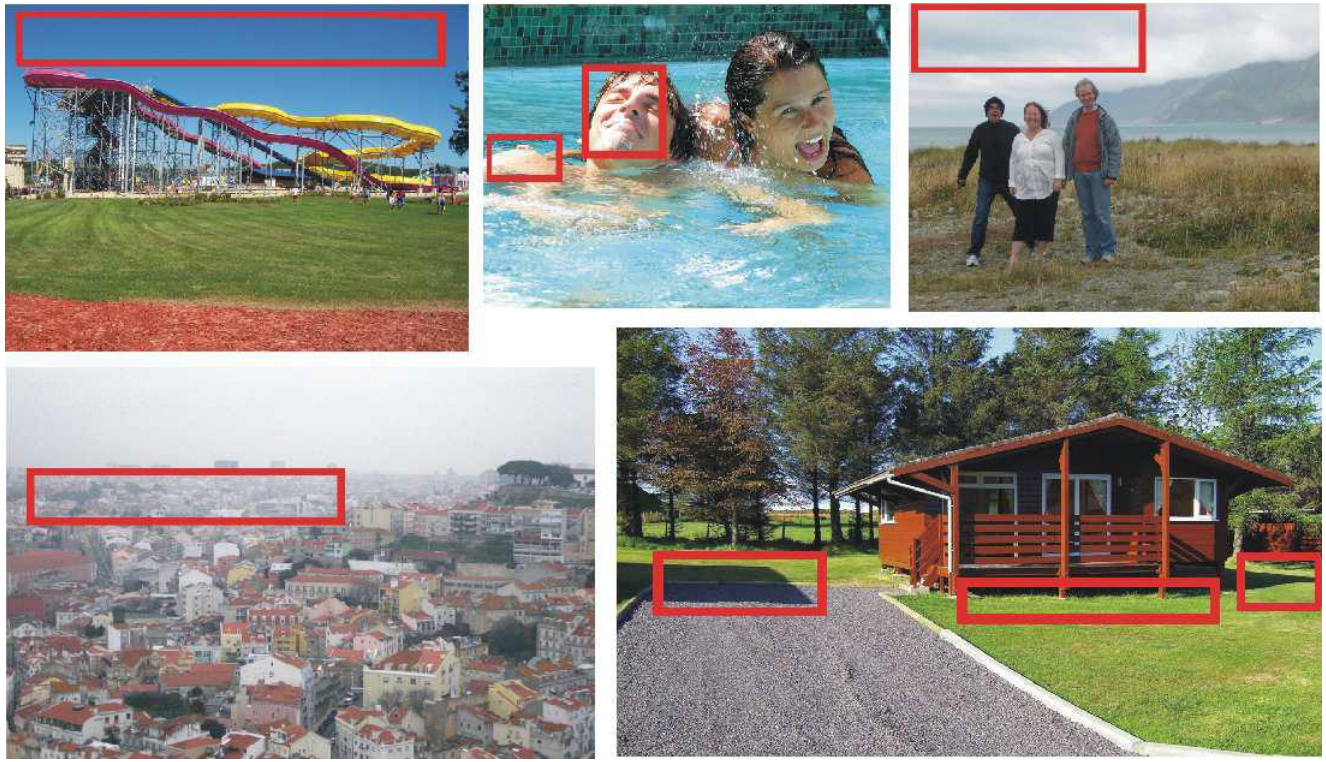
mean lightness 32.41

mean lightness 58.23

intensity distribution of 5K sunny and 5K cloudy images



How human recognize the weather?

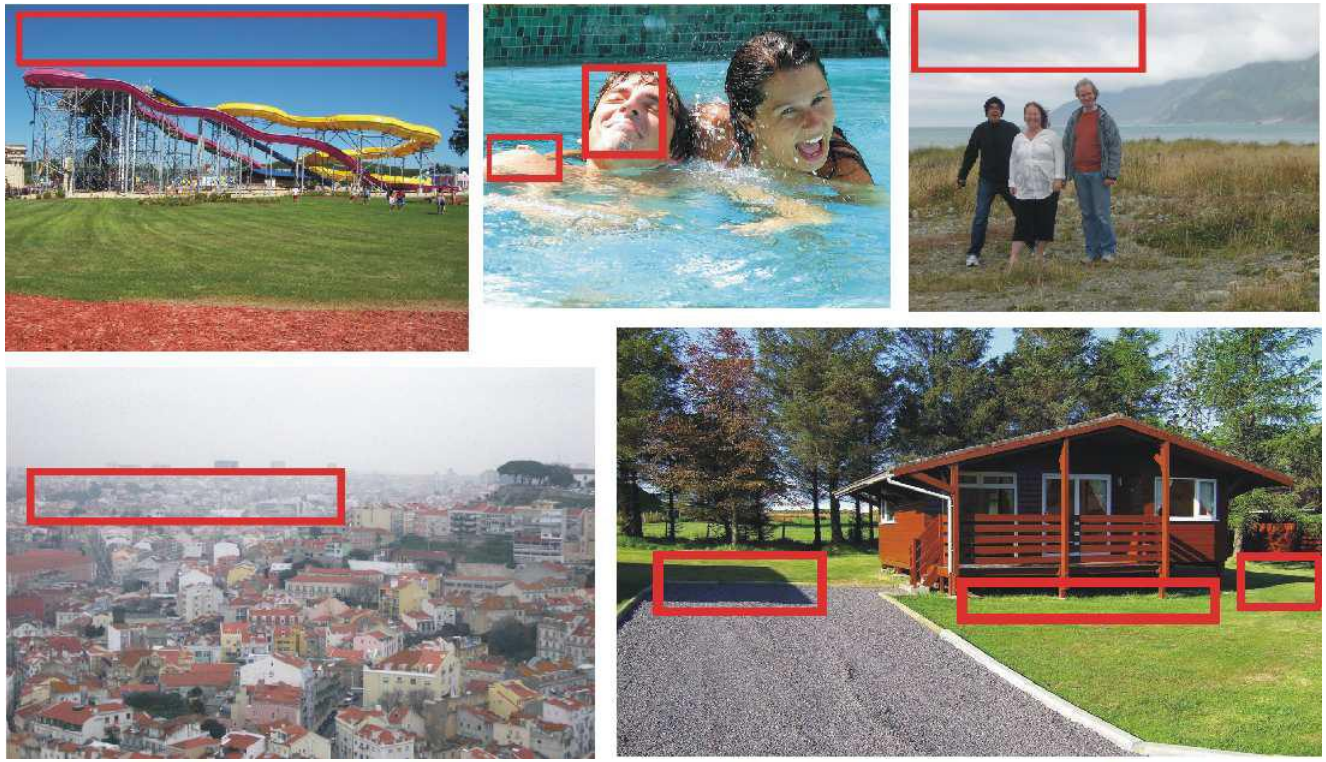


Weather Cue!

How human recognize the weather?

Weather Cue!

How human recognize the weather?



Weather Cue!

Weather Cue Feature

- 621-D feature vector

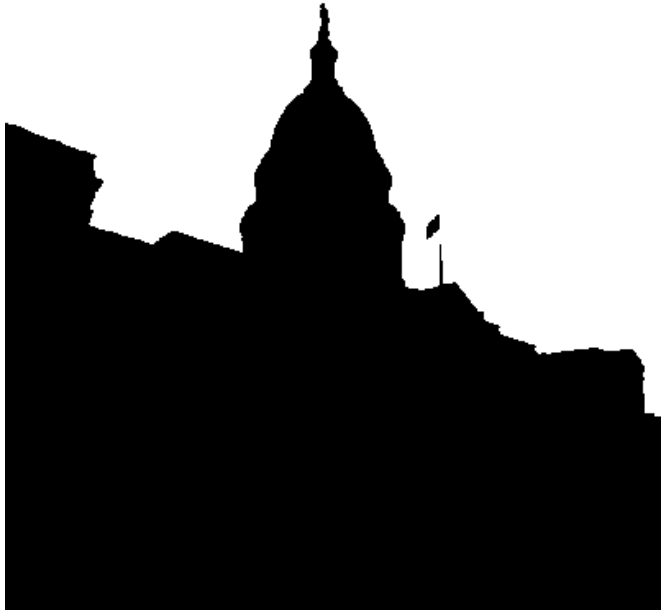
  [**sky**; **shadow**; **reflection**; **contrast**; **haze**]

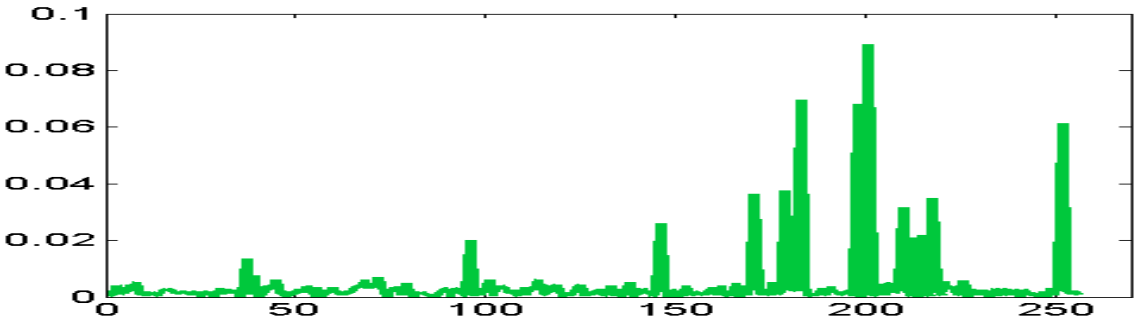
$$[\ \mathbf{f}_{sk};\ \mathbf{f}_{sh};\ \mathbf{f}_{re};\ \mathbf{f}_{co};\ \mathbf{f}_{ha}\ ]$$

- Existence vector

$$[\ v_{sk}\ \ v_{sh}\ \ v_{re}\ \ v_{ha}\ ]^T$$

Sky (256)





How to set **sky**?

Evidence Score:

$$v_{sk} = \begin{cases} 1 & \text{if } A > 0.5 \\ \min\{2A, 1\} & \text{otherwise} \end{cases}$$

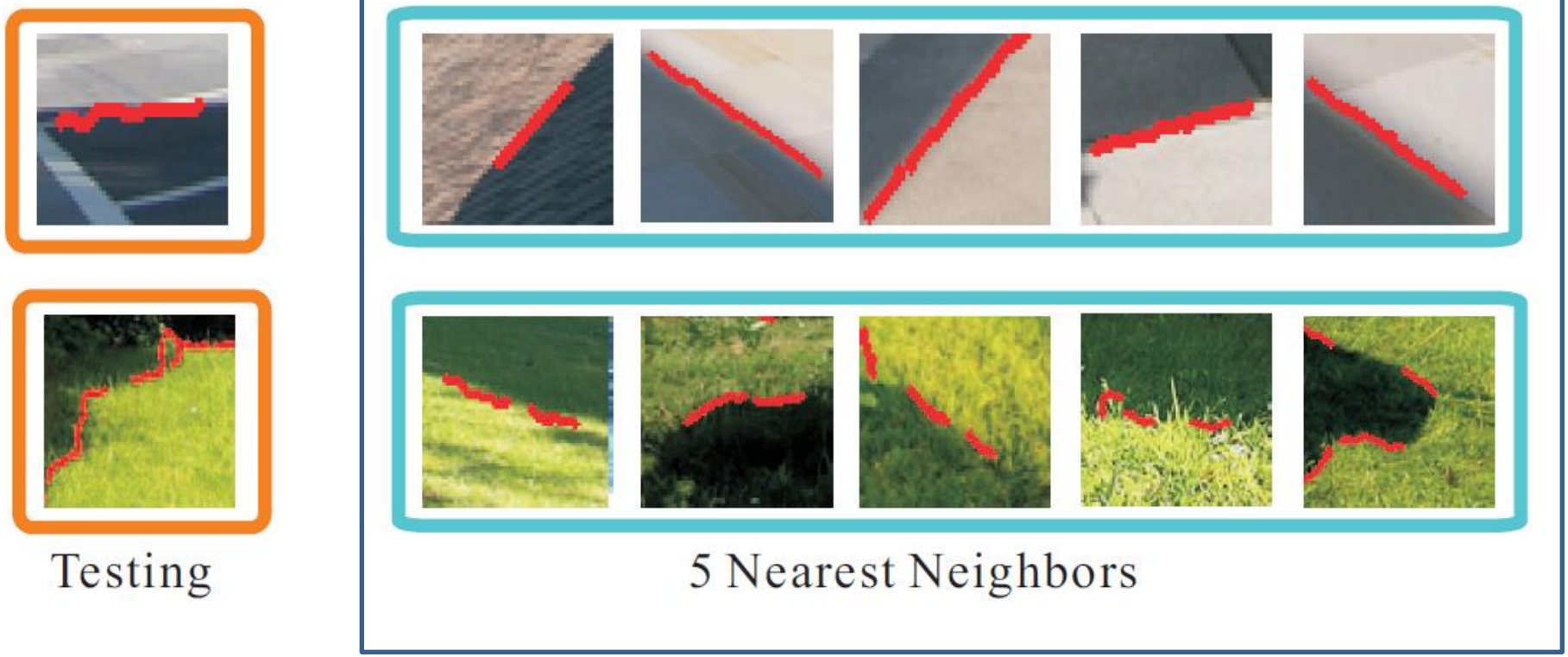
Sky size/ image size

Shadow (10)

Only works on sunny day!

Shadow detector [Lalonde et al, IJCV 2012]

Shadow (10)



Matching in Sunny Training dataset

Shadow (10)

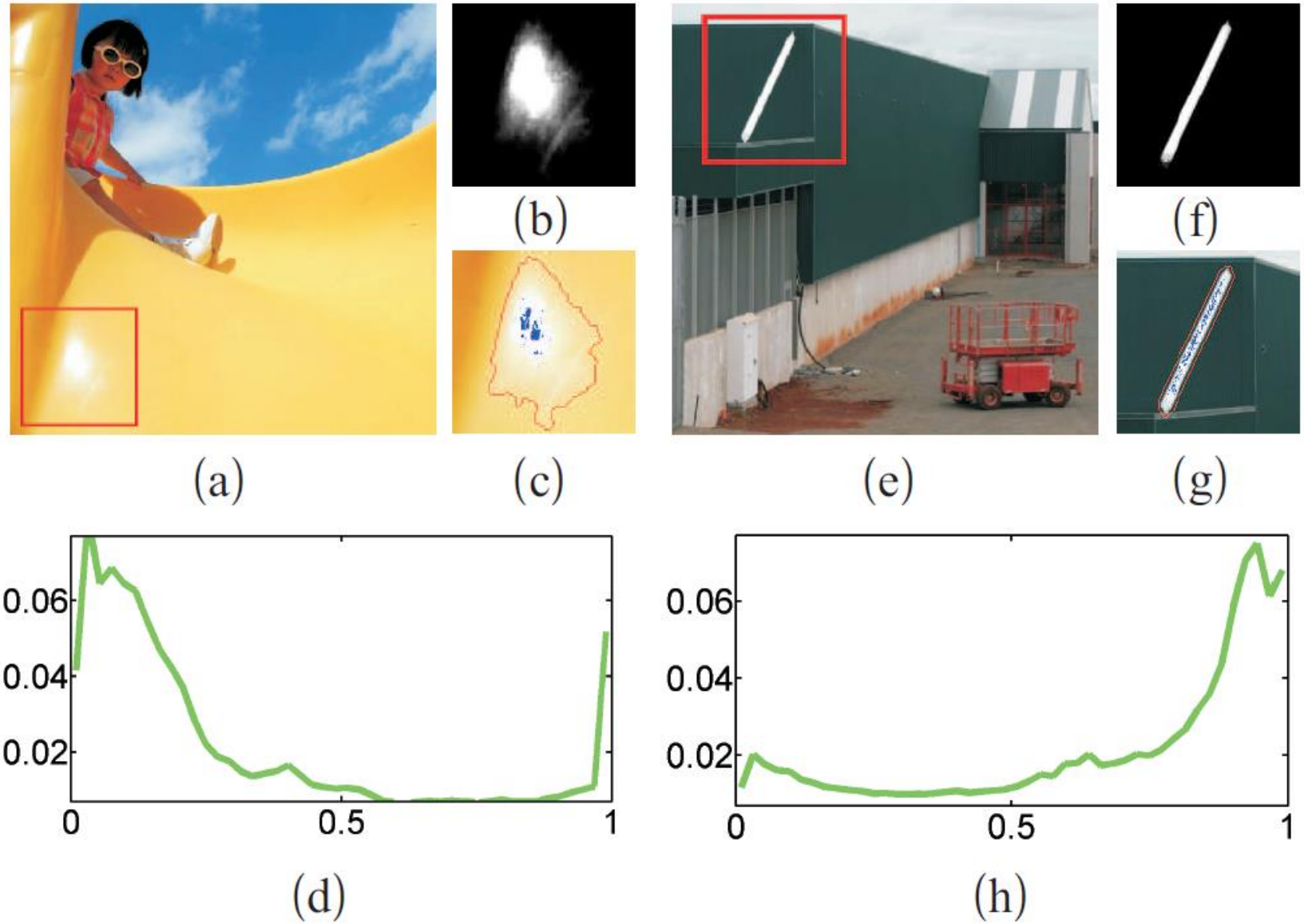
Shadow feature:

Top 10 matching errors.

Evidence score

Matching errors in sunny shadow dataset.

Reflection (100)

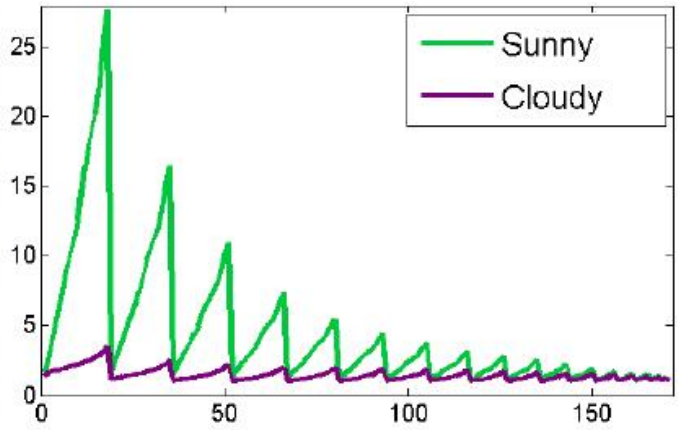


Shadow (10)

Evidence Score: v_{sh}

1 if white pixels are present in the image
0 otherwise.

Contrast (170)



pi as the *ith* percentile in the input image
in the saturation map. The set of all saturation
percentile ratios is given by $\{r | r = pi/pj\ ,\ \forall i > j\}$,

Haze (84)

- Cloudy weather is often hazy
- Haze priors [He et al CVPR'09]

Feature:

Spatial Pyramid max-pooling feather on dark prior

Evidence Score: v_{ha}

Median value of dark channel



Input dark channel Dehaze

Weather Cue Feature

- 621-D feature vector

  [**sky**; **shadow**; **reflection**; **contrast**; **haze**]

$$[\ \mathbf{f}_{sk};\ \mathbf{f}_{sh};\ \mathbf{f}_{re};\ \mathbf{f}_{co};\ \mathbf{f}_{ha}\ ]$$

- Existence vector

$$[\ v_{sk}\ \ v_{sh}\ \ v_{re}\ \ v_{ha}\ ]^T$$

Weather Cue Feature

- 621-D feature vector

  [**sky**; **shadow**; **reflection**; **contrast**; **haze**]

$$[\ \mathbf{f}_{sk};\ \mathbf{f}_{sh};\ \mathbf{f}_{re};\ \mathbf{f}_{co};\ \mathbf{f}_{ha}\ ]$$

- Existence vector

Apply SVM on it?

$$[\ v_{sk}\ \ v_{sh}\ \ v_{re}\ \ v_{ha}\ ]^T$$

Collaborative Learning

No Sky

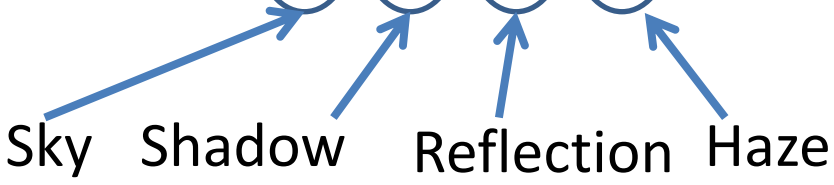
No Shadow

No Reflection

Weather cues in images in NOT homogeneous

Collaborative Learning

Evidence vector: $[\, v_{sk} \; v_{sh} \; v_{re} \; v_{ha} \,]^T$



Weather cues in images in NOT homogeneous

Collaborative Learning

M subsets

$\{\Omega_1, \ldots, \Omega_M\}$

M cluster centers

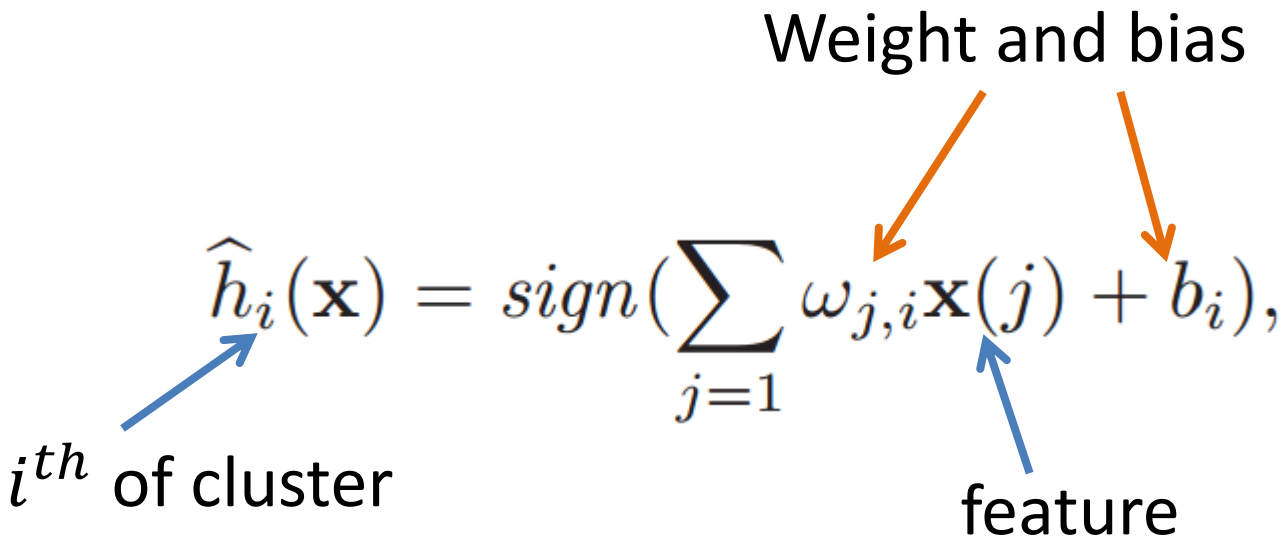
$\{\widehat{e}_1, \ldots, \widehat{e}_M\}$

"sky + shadow" $\{\mathbf{0.90}, \mathbf{0.87}, 0.26, 0.11\}$

"sky + haze" $\{\mathbf{0.94}, 0.24, 0.27, \mathbf{0.84}\}$

Cluster based on evidence vectors

Collaborative Learning



For single cluster (weather pattern)

Collaborative Learning

$$\min_{\omega_{j,i},b_i,\zeta_{i,k}} \sum_{j=1}^{p} \omega_{j,i}^2 + C \sum_{k\in\Omega_i} \zeta_{i,k}$$

$$\text{s.t. } y_k\Big(\sum_{j=1}^{p} \omega_{j,i}\mathbf{x}_k(j) + b_i\Big) \geq 1 - \zeta_{i,k},$$

$$\zeta_{i,k} \geq 0,\ \forall\, k \in \Omega_i,$$

standard SVM

Collaborative Learning

$$h(\mathbf{x}, e) = sign[\sum_{i=1}^{M} s(\widehat{e}_i, e)\widehat{h}_i(\mathbf{x})],$$

$$s(\widehat{e}_i, e) = \frac{\exp(-\frac{\|\widehat{e}_i - e\|_2^2}{2\sigma^2})}{\sum_i^M \exp(-\frac{\|\widehat{e}_i - e\|_2^2}{2\sigma^2})},$$

Collaborative Learning

voters

$$h(\mathbf{x}, e) = sign[\sum_{i=1}^{M} s(\widehat{e}_i, e)(\sum_{j=1}^{p} \omega_{j,i}\mathbf{x}_k(j) + b_i)].$$

$$s(\widehat{e}_i, e) = \frac{\exp(-\frac{\|\widehat{e}_i - e\|_2^2}{2\sigma^2})}{\sum_i^M \exp(-\frac{\|\widehat{e}_i - e\|_2^2}{2\sigma^2})},$$

Collaborative Learning

$$\min_{\omega_{j,i},b_i,\xi_t,\zeta_{i,k}} \sum_{i=1}^{M}\sum_{j=1}^{p}\omega_{j,i}^2 + C_1\sum_{i=1}^{M}\sum_{k\in\Omega_i}\zeta_{i,k} + C_2\sum_{t=1}^{N}\xi_t$$

Effective voters

$$\text{s.t. } y_k(\sum_{j=1}^{p}\omega_{j,i}\mathbf{x}_k(j) + b_i) \geq 1 - \zeta_{i,k},$$

$$\zeta_{i,k} \geq 0,\ \forall\, k \in \Omega_i,\ \forall i = 1,\ldots,M$$

All voters

$$y_t[\sum_{i}^{M} s(\widehat{e}_i, e_t)(\sum_{j=1}^{p}\omega_{j,i}\mathbf{x}_t(j) + b_i)] \geq 1 - \xi_t$$

$$\xi_t \geq 0,\ \forall\, i = 1,\ldots,M,\ \forall\, t = 1,\ldots,N$$

Langrage multiplier

Results

	Sky	Shadow	Reflection	Contrast	Haze
normalized accuracy	39.3 ± 2.1	28.2 ± 2.4	23.0 ± 2.6	35.5 ± 2.2	30.2 ± 1.7

Table 1. Classification results (mean $\pm$ variance) using individual weather cues.

	SVM	Adaboost	LLC [19]	ScSPM [22]	Ours
Normalized accuracy	41.2 ± 2.2	36.4 ± 2.3	0.3 ± 0.1	0.2 ± 0.1	**53.1** ± 2.2

Table 2. Classification statistics (mean $\pm$ variance) of different classification methods.

	Lalonde *et al.* [9]	Yan *et al.* [21]	Roser and Moosmann [16]	Ours
normalized accuracy	39.5 ± 2.3	24.6 ± 2.6	26.2 ± 2.3	**53.1** ± 2.2

Table 3. Classification statistics (mean $\pm$ variance) of different methods.

Normalized accuracy: *max{ (a − 0.5)/(1 − 0.5),0 }*
where *a* is the accuracy obtained traditionally.

Sunny

Cloudy

Multi-class weather classification (7 classes)

雨天

雪天

这都认得出，你们人类真牛…

Visibility Estimation
能见度估计

Smoggy Beijing

- Extremely low visibility



Smog in Beijing

- Smog is serious problem.

Smog shrouds Athens as Greeks choke on fuel bills

Nefeli Agkyridou, Associate producer

Monday, 6 Jan 2014 | 9:17 AM ET

CNBC

As night falls, thick clouds of black smoke cover Greece's sky, making it hard to breathe outside. The familiar winter smell of wood burning in fireplaces has turned into a public health threat, with cash-strapped Greek households turning to firewood for heat .

Smog has long plagued Athens. But the problems reported in the 1990s were largely the consequence of an economic boom, when an average family in the capital owned more than one car and industrial production was at its peak. But time around, it is a consequence of the financial crisis.

Eco Images | Universal Images Group | Getty Images

FEATURED

Putin risks upstaging talks on calming Ukraine crisis
Foreign ministers will try to defuse the Ukraine crisis on Thursday but will risk being upstaged by Russian President Vladimir Putin.

Russian economy hurting
First quarter economic growth in Russia slowed and Moscow's economy minister is attributing it to uncertainty over the Ukraine crisis.

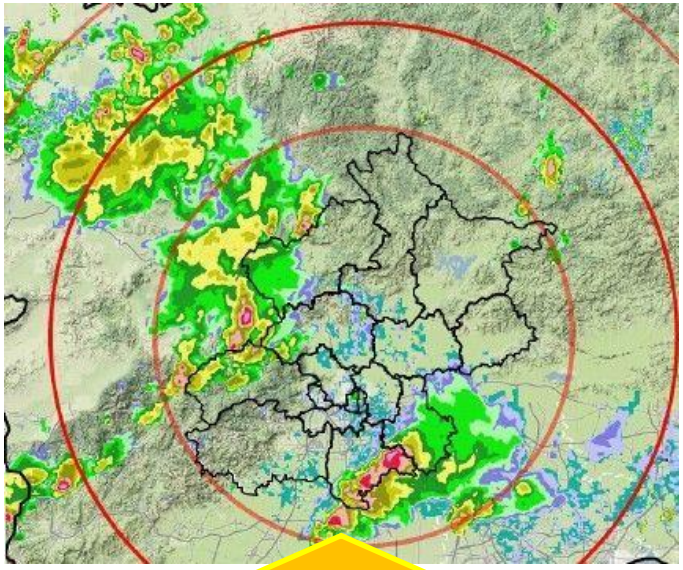
What's next for Ukraine?
As Russia warns that Ukraine is on the verge of a civil war, here's a look at what could be in store for Ukraine - and what it means for the rest of the world.

Starbucks to relocate European HQ to UK: Report
Starbucks said it decided to move its European headquarters to the U.K. from the Netherlands following criticism over its low tax payments, The Times reported.

Burning season in Indonesia

Weather Monitor

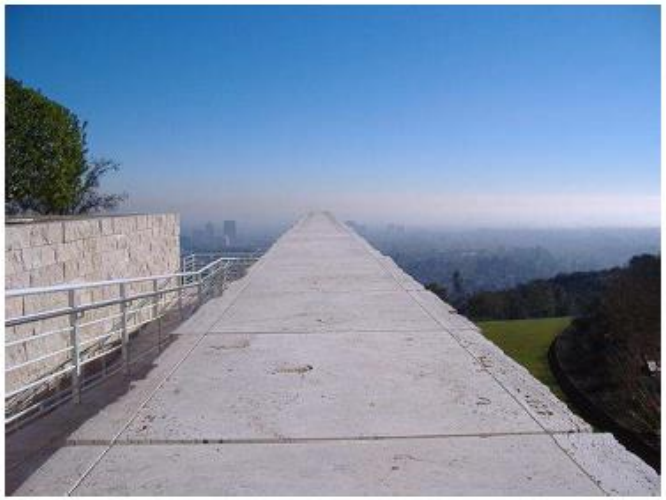
- Real-time
- Geometry dense



We already have haze-removing methods!

Input dark channel Dehaze

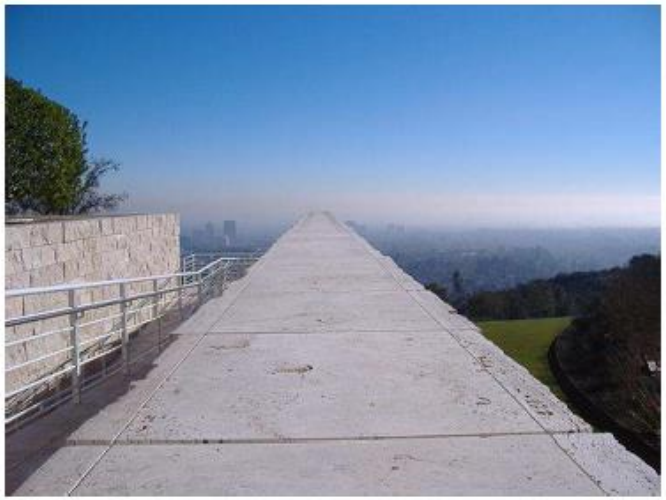
[He *et al*. CVPR 2009]



Input dark channel

Input dark channel Dehaze

[He *et al*. CVPR 2009]



Input dark channel

Without high-level understanding

Input dark channel Dehaze

Visibility Estimation

But, how to learn?

Label the visibility for each image?

Visibility Estimation

Do you know the visibility (能见度)?

Visibility: measure of the distance at which an object or light can be clearly discerned.

Difficult to collect!

Visibility Estimation

300 m ?
500 m ?
700 m ?
……
900 m ?

Visibility Estimation

Do you know the visibility?

Difficult to collect!

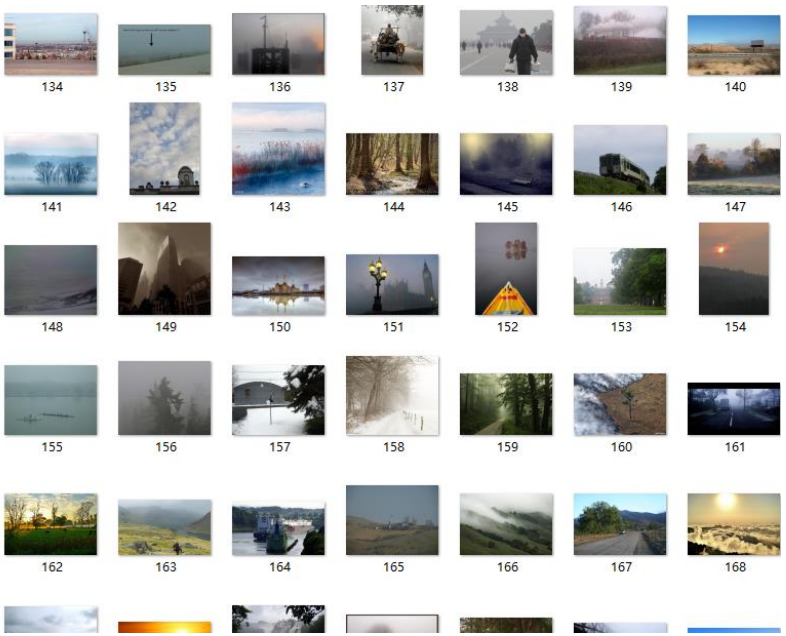
Visibility: measure of the distance at which an object or light can be clearly discerned.

Visibility Estimation

>

Which one has larger visibility degree?

Visibility Estimation



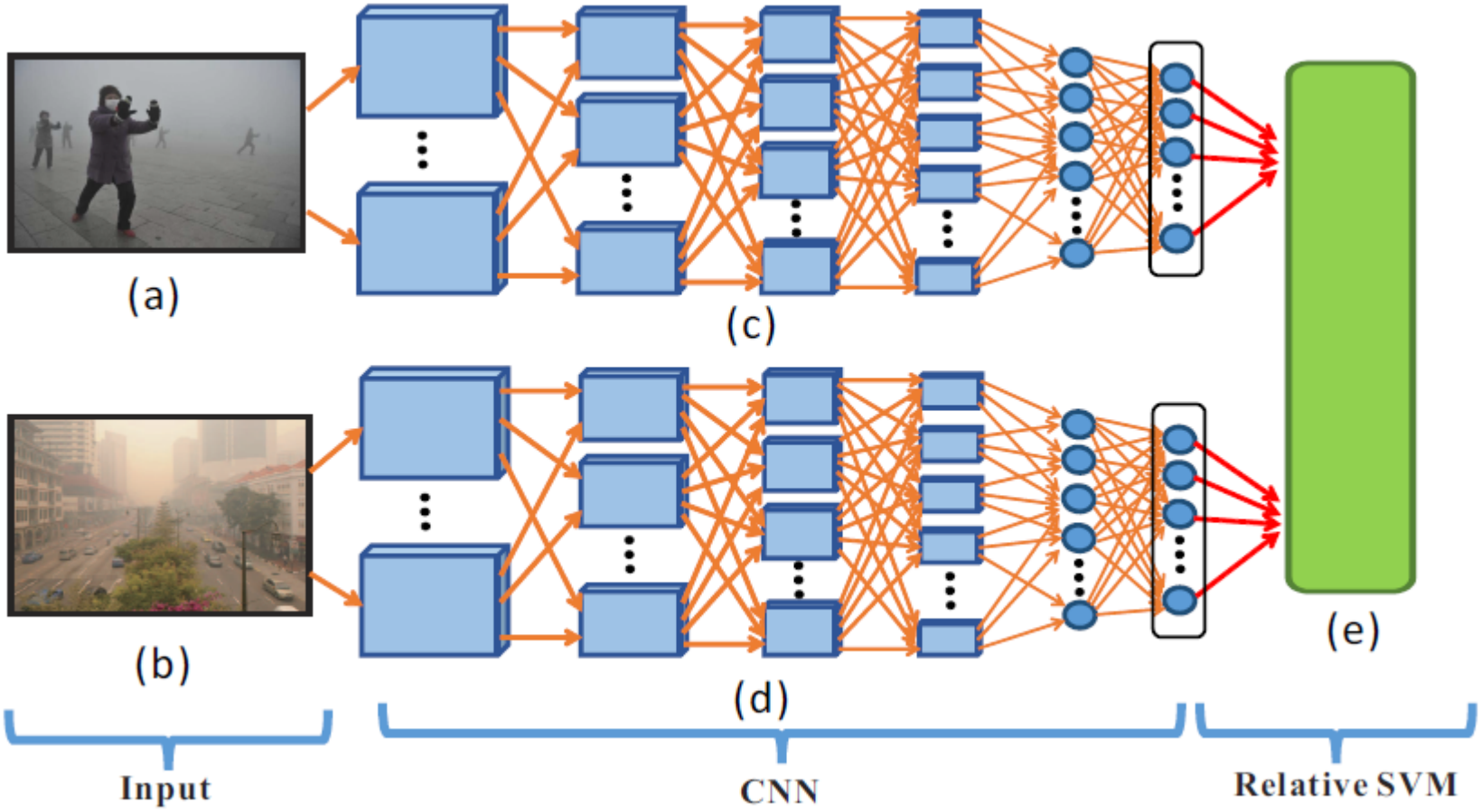
Visibility Database

million human responses

40,000 images

Data-driven

A new CNN Framework






0.95 0.74 0.32 0.08




0.90 0.55 0.42 0.23




0.84 0.81 0.20 0.11




0.87 0.57 0.32 0.18

$y^o = 2.0$ km
$\widehat{y} = 2.4$ km

$y^o = 23.0$ km
$\widehat{y} = 26.5$ km

$y^o = 6.0$ km
$\widehat{y} = 5.2$ km

$y^o = 6.9$ km
$\widehat{y} = 5.7$ km

廣告時間

广告时间: Object Detection (deep learning)

Efficient Square Localization for Object Detection
Cewu Lu and Chi-Keung Tang （**CCF A类**）
International Conference on Computer Vision (**ICCV**) 2015

Contour Box: Rejecting Object Proposals Without Explicit Closed Contours
Cewu Lu and Chi-Keung Tang （**CCF A类**）
International Conference on Computer Vision (**ICCV**) 2015

Personal Objects Discovery in First-Person Perspective Video;
Cewu Lu, Renjie Liao and Jiaya Jia. （**CCF A类**）
IEEE Transactions on Image Processing (**TIP**); 2015

Complexity-Adaptive Distance Metric for Object Proposals Generation;
Xiao Yao, **Cewu Lu** and Chi-Keung Tang （**CCF A类**）
IEEE Conference on Computer Vision and Pattern Recognition (**CVPR**) 2015

Deep LAC: Deep Localization, Classification for Fine-grained Recognition;
Di Lin, Xiaoyong Shen, **Cewu Lu** and Jiaya Jia （**CCF A类**）
IEEE Conference on Computer Vision and Pattern Recognition (**CVPR**) 2015

广告时间: Object Detection (deep learning)

Box Aggregation for Proposal Decimation: Last Mile of Object Detection
Shu Liu, **Cewu Lu** and Jiaya Jia （**CCF A类**）
International Conference on Computer Vision (**ICCV**) 2015

Improving Object Recognition with the l-Channel;
Cewu Lu, Efstratios Tsougenis and Chi-Keung Tang.,
Pattern Recognition (**PR**), 2015.**(CCF B类)**

IMAGENET

14,197,122 images, 21841 synsets indexed

Explore Download Challenges Publications CoolStuff About

Not logged in. Login | Signup

第四名

1-HKUST: Object Detection in ILSVRC 2014

Cewu Lu Hao Chen Qifeng Chen Hei Law Yao Xiao Chi-Keung Tang

Airplane

Car

Person

al Recognition Challenges (ILSVRC) is the one of the more important big data challenges in the world. We particip
ived the 4th place among the 38 teams. Our system involves a number of novel techniques on localization and rec
generated from selective search, and a novel technique on regressing bounding boxes using deep learning is used
candidate proposal, we adopted three features in our system, namely, RCNN features, IFV features and DPM featu
bination functions are learned to improve object recognition. Furthermore, background priors and object interacti
compared with other teams

广告时间: Activity Understanding

Range-Sample depth feature for Action Recognition;
Cewu Lu, Jiaya Jia and Chi-Keung Tang. **(CCF A类）**
IEEE Conference on Computer Vision and Pattern Recognition (**CVPR**) 2014

Abnormal event detection at 150 FPS in MATLAB;
Cewu Lu, Jianping Shi and Jiaya Jia **（CCF A 类)**
IEEE International Conference on Computer Vision (**ICCV**) 2013

Scale Adaptive Dictionary Learning.
Cewu Lu, Jianping Shi and Jiaya Jia. **（CCF A类)**
IEEE Transactions on Image Processing (**TIP**). 2014

Abnormal event detection at 150 FPS in MATLAB;
Cewu Lu, Jianping Shi and Jiaya Jia
IEEE International Conference on Computer Vision (**ICCV**) 2013

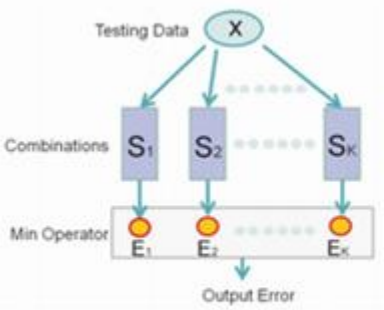


Figure 1. Our testing architecture. $\mathbf{X}$ denotes testing data. $\{\mathbf{S}_1, \ldots, \mathbf{S}_K\}$ are learned combinations, with each $\mathbf{S}_i \in \mathbb{R}^{p \times s} (s \ll q)$. E_i is the corresponding least square reconstruction error. The final error is the minimum among all combinations.

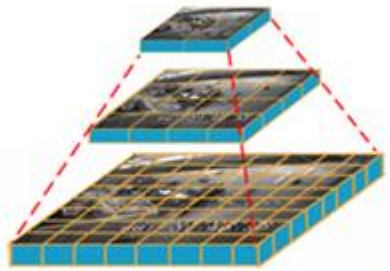


Figure 2. Pyramid region architecture. A frame is resized into 3 different scales. In each scale the frame is partitioned into several regions.

(a) events (b) maps (c) maps

Figure 3. Two abnormal events and their corresponding abnormal patches under two different scales in the Avenue dataset.

Downloads

"Abnormal Event Detection at 150 FPS in MATLAB"
Cewu Lu, Jianping Shi, Jiaya Jia
IEEE International Conference on Computer Vision (**ICCV**), 2013

[Paper]

[BibTeX]

[Code] (upon request to Dr. Lu <lucewu06@gmail.com>)

[Avenue Dataset]

The End, Thanks