Object Detection Using CNNs

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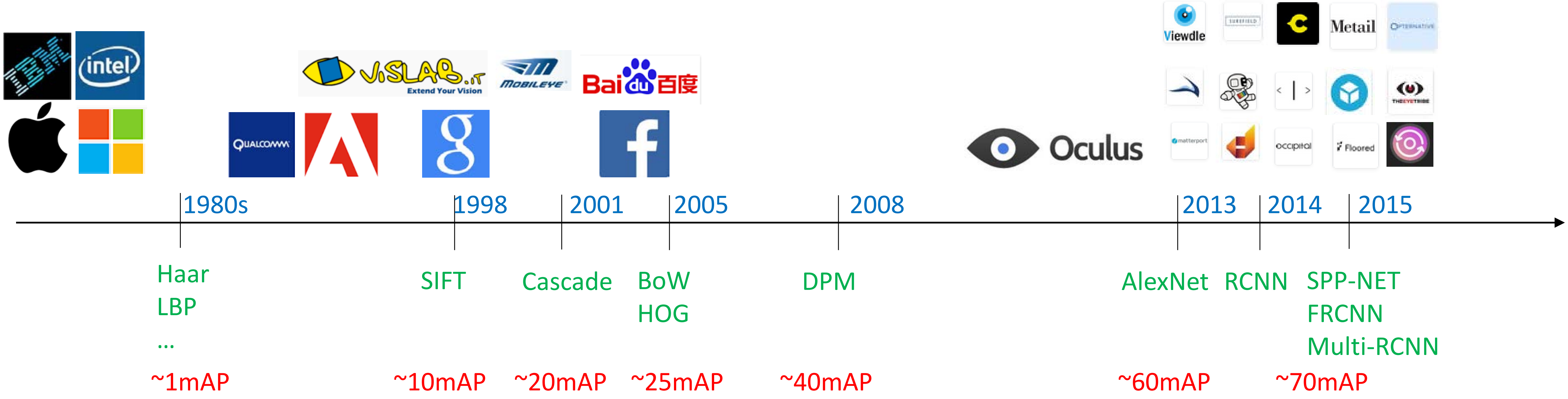
University of Southern California

History in Object Detection



1980s
Haar
LBP
...
~1mAP

1998
SIFT
~10mAP

2001
Cascade
~20mAP

2005
BoW
HOG
~25mAP

2008
DPM
~40mAP

2013
AlexNet
~60mAP

2014
RCNN

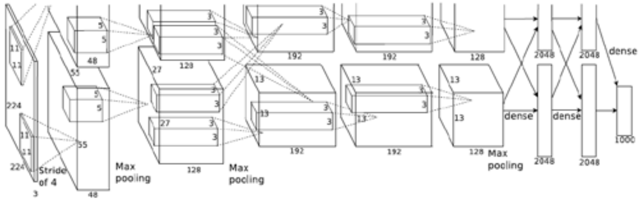
2015
SPP-NET
FRCNN
Multi-RCNN
~70mAP

mAP: Mean Average Precision

Object Detection with DNN

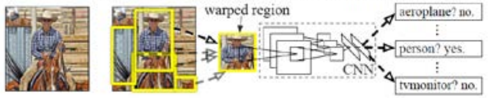
2013

AlexNet



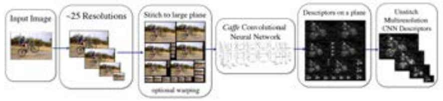
2014

RCNN

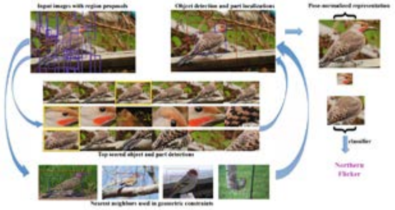


Caffe

DenseNet



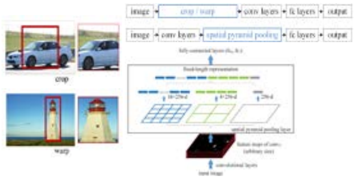
Part-Based R-CNN



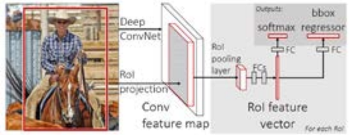
Input images with region proposals
Object detection and part localizations
Pose-normalized representation
Top scored object and part detections
Nearest neighbors used in geometric constraints
classifier
Northern Flicker

2015

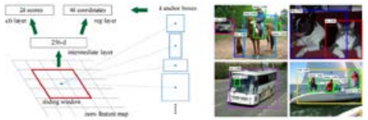
SPP-Net



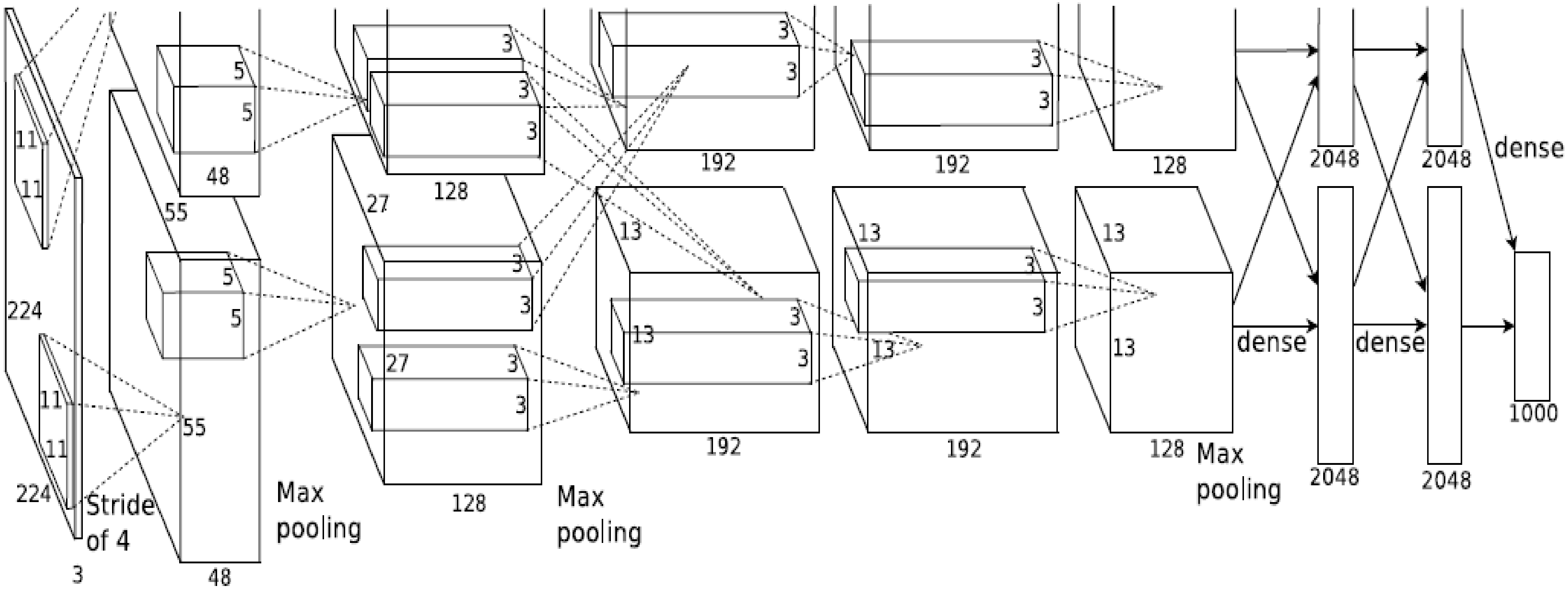
Fast R-CNN



Faster R-CNN



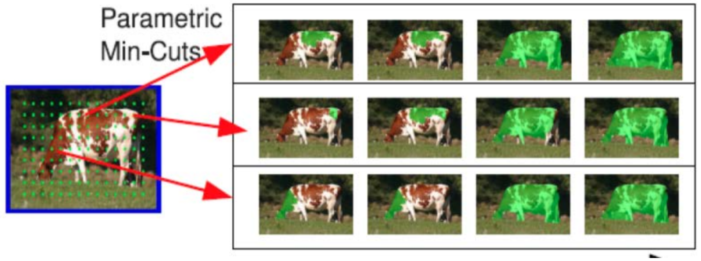
Alex Net (2013)

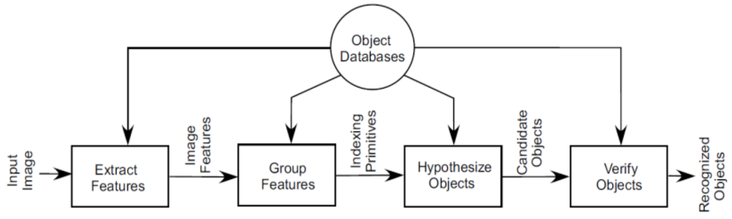


A. Krizhevsky, I. Sutskever, and G. E. Hinton. Imagenet classification with deep convolutional neural networks.

Region Proposal with CNN (RCNN)

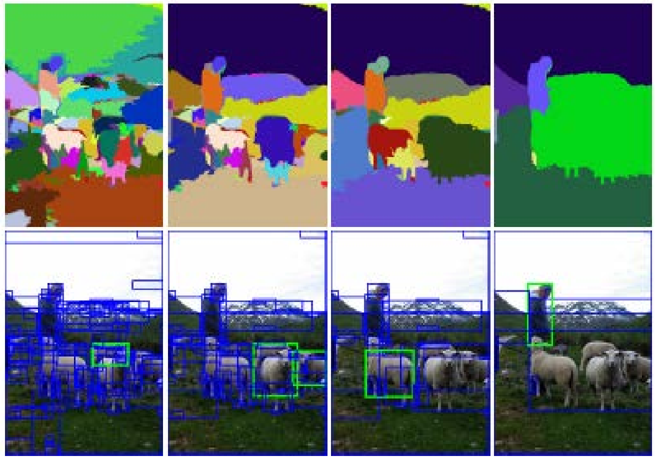
Constraint Parametric Min-Cut





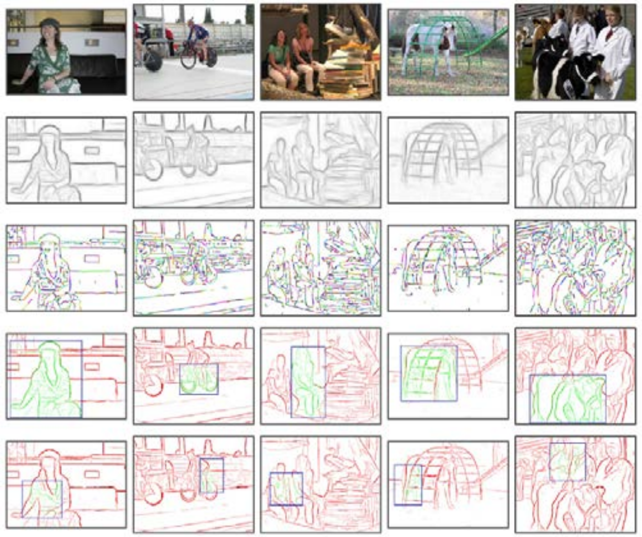
J. Carreira and C.sminchisescu. CPMC Automatic object segmentation using constrained parametric min-cust. In CVPR, 2012

Selective Search



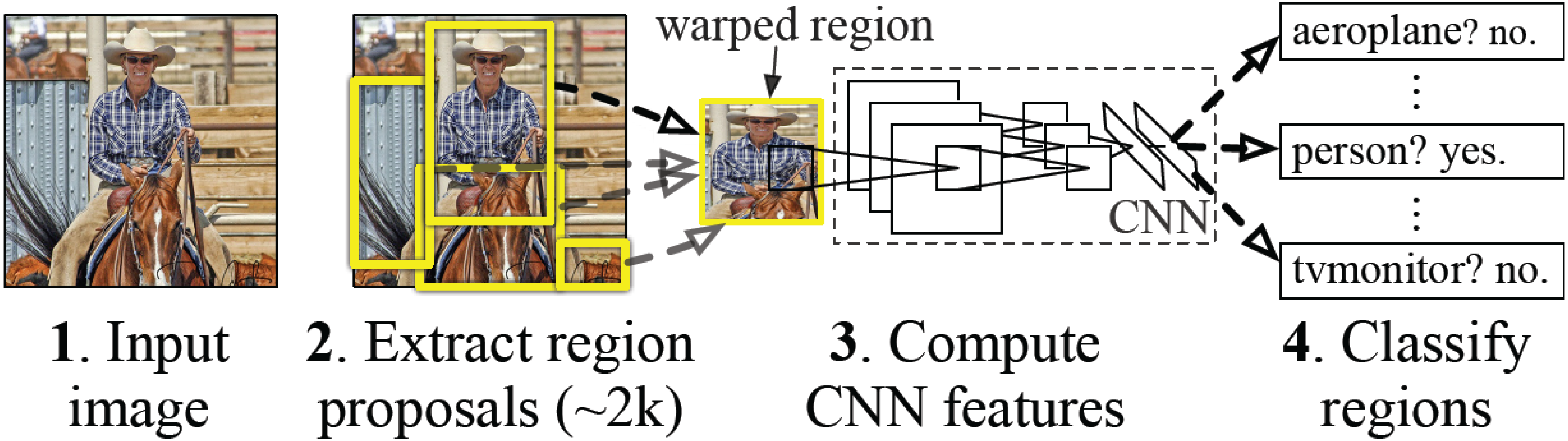
J.R.R Uijlings, K.E.A. Van De Sande, T. Gevers, and A.W.M. Smeulders, Selective Search for Object Recognition. In IJCV 2013

EdgeBox



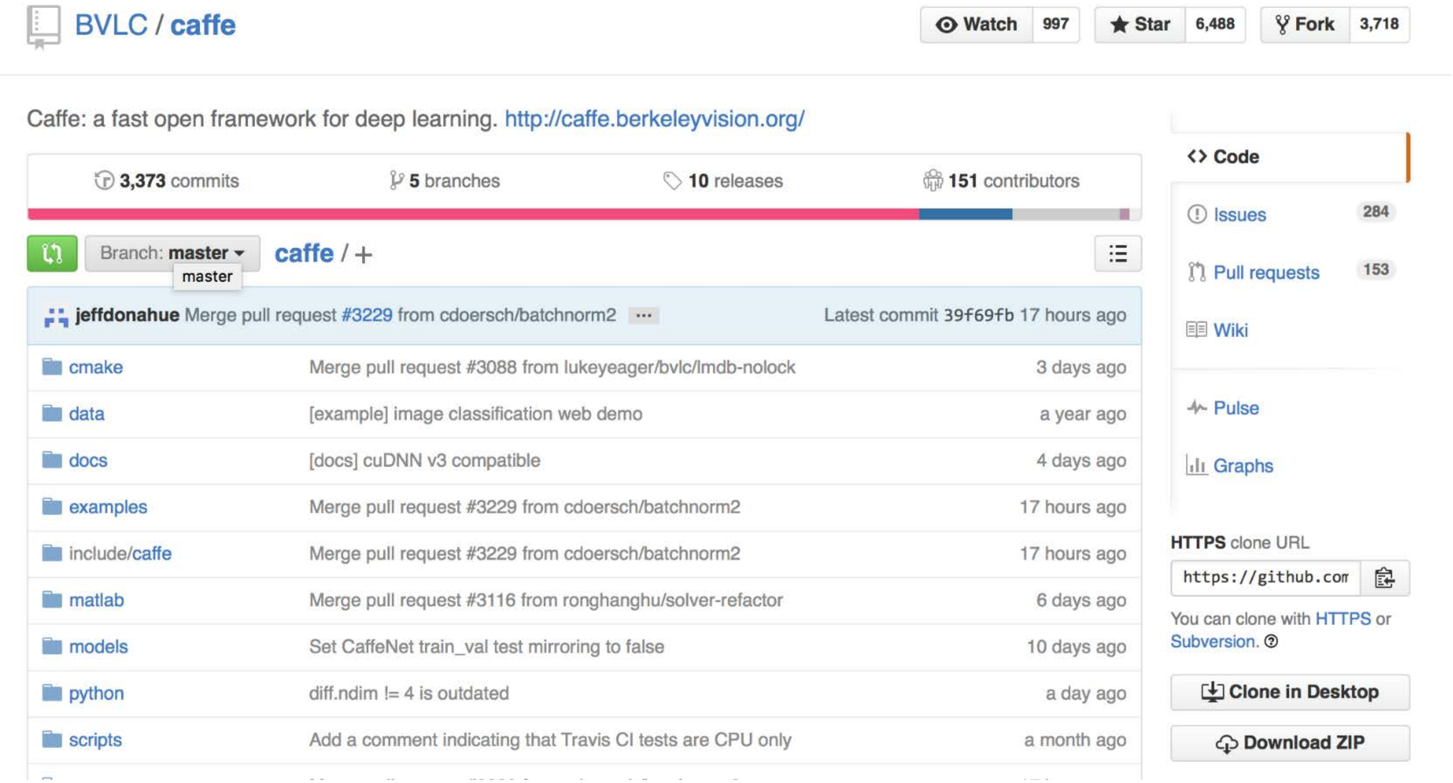
C. L. Zitnick and P. Dollar, “Edge boxes: Locating object ´ proposals from edges,” in ECCV, 2014.

RCNN Flowchart



Ross Girshick, Jeff Donahue, Trevor Darrell, Jitendra Malik, Rich Feature
Hierachies for Accurate Object Detection and Semantic Segmentation

Caffe: Public Domain Software



Caffe: a fast open framework for deep learning. http://caffe.berkeleyvision.org/

3,373 commits 5 branches 10 releases 151 contributors

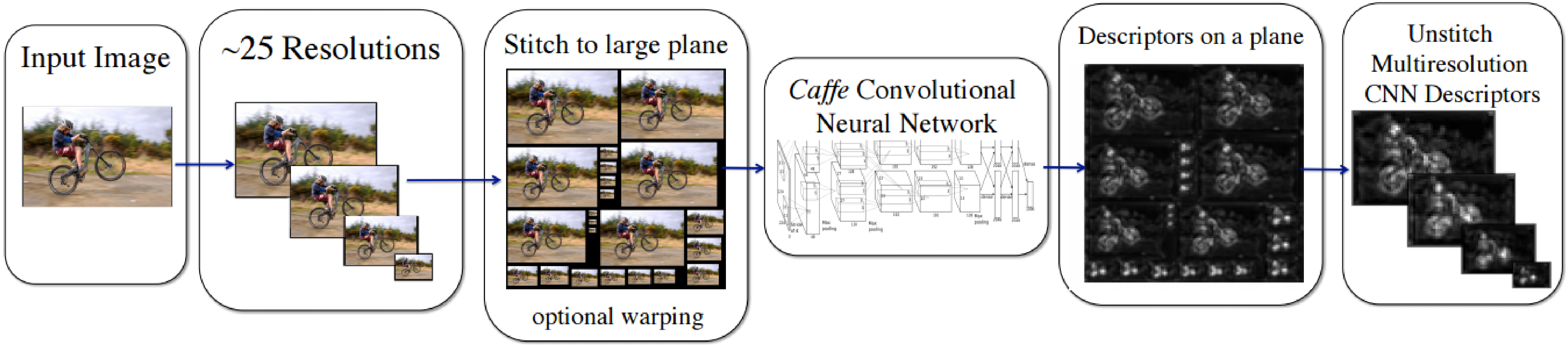
jeffdonahue Merge pull request #3229 from cdoersch/batchnorm2 … Latest commit 39f69fb 17 hours ago

cmake	Merge pull request #3088 from lukeyeager/bvlc/lmdb-nolock	3 days ago
data	[example] image classification web demo	a year ago
docs	[docs] cuDNN v3 compatible	4 days ago
examples	Merge pull request #3229 from cdoersch/batchnorm2	17 hours ago
include/caffe	Merge pull request #3229 from cdoersch/batchnorm2	17 hours ago
matlab	Merge pull request #3116 from ronghanghu/solver-refactor	6 days ago
models	Set CaffeNet train_val test mirroring to false	10 days ago
python	diff.ndim != 4 is outdated	a day ago
scripts	Add a comment indicating that Travis CI tests are CPU only	a month ago

You can clone with HTTPS or Subversion.

R. Girshick, J. Donahue, T. Darrell, and J. Malik. Rich feature hierarchies for accurate object detection and semantic segmentation.

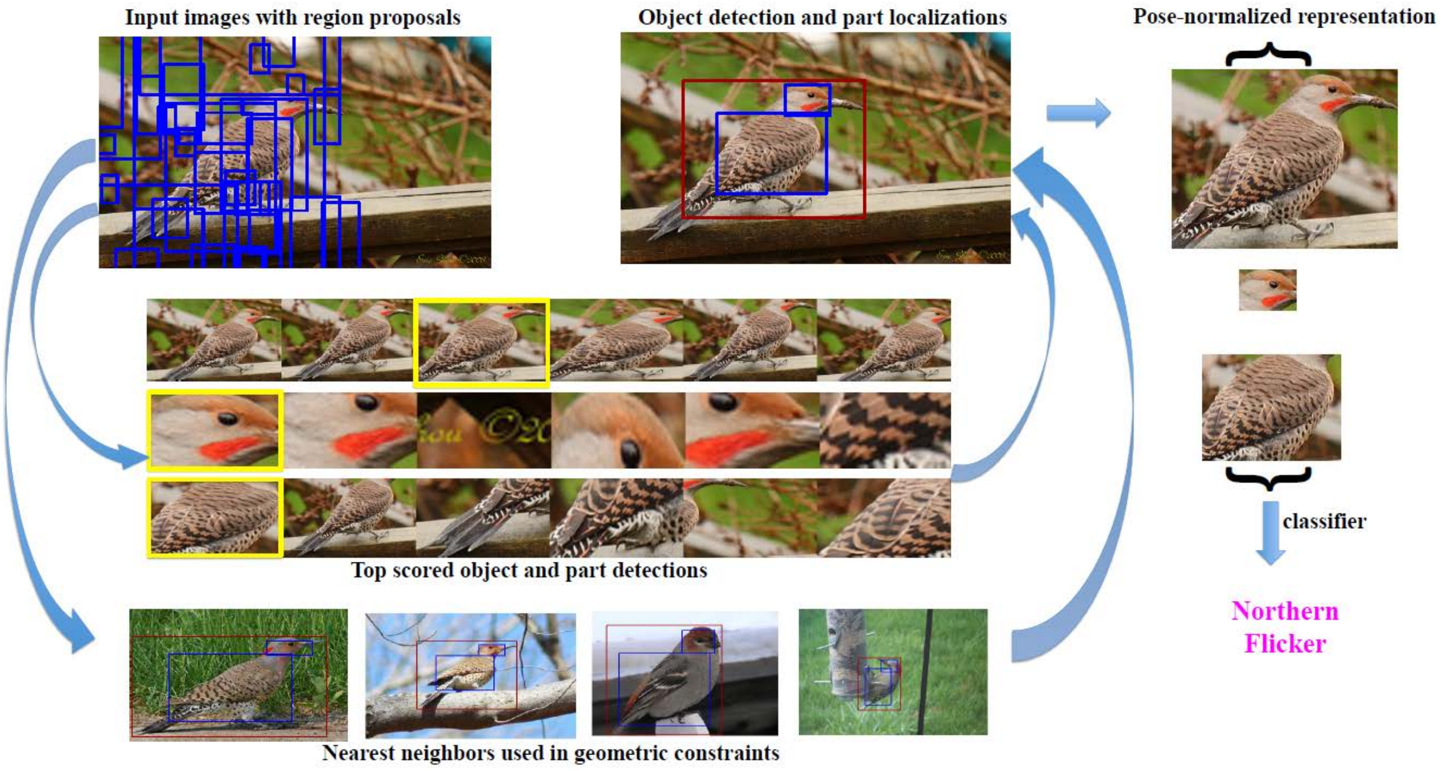
Dense Net



F.Iandola, M. Moskewicz, S. Karayev, R. Girshick, T. Darrell, K. Keutzer, DenseNet: Implementing Efficient ConvNet Descriptor Pyramids

Part-based CNN

- Fine-grained Detection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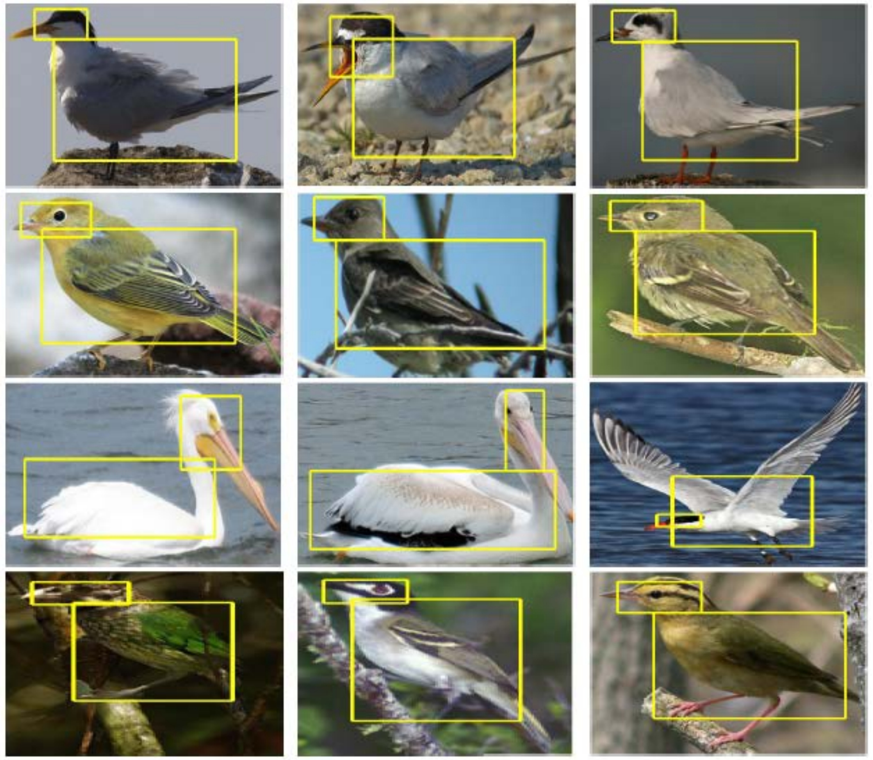
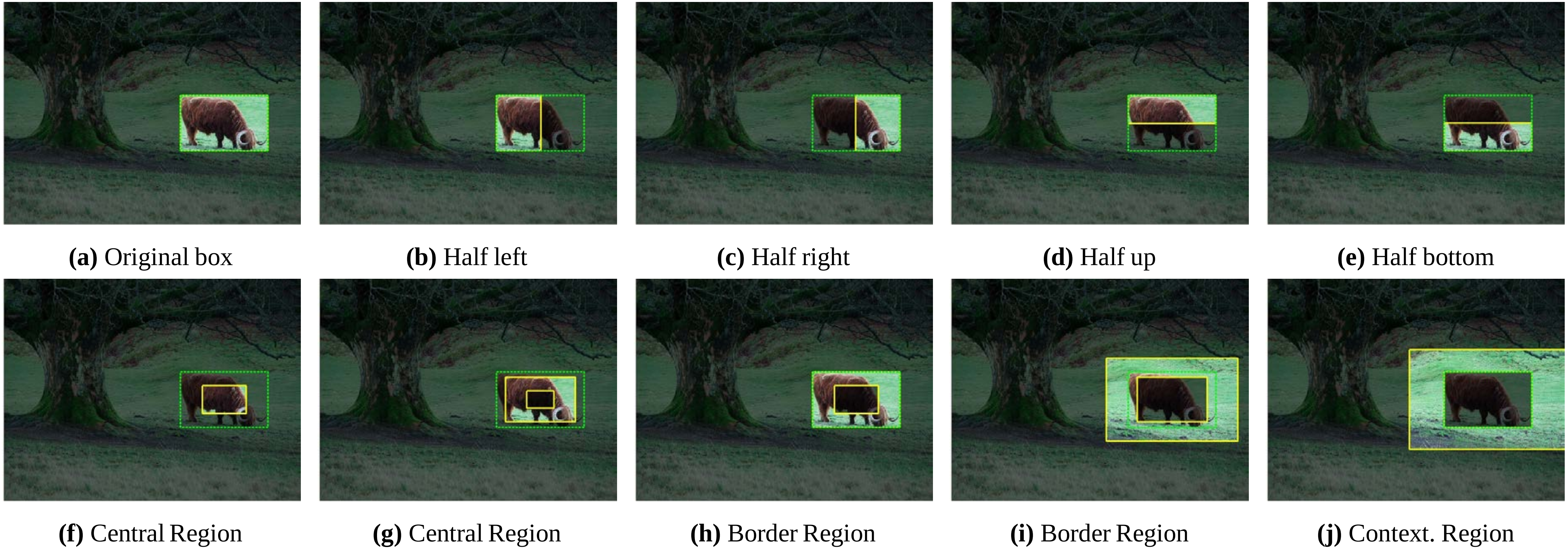


Ning Zhang, Jeff Donahue, Ross Girshick, Trevor Darrell , Part-based R-CNNs forFine-grained Category Detection

Multi-region CNN

- Multi-region & semantic segmentation-aware CNN model:



(a) Original box

(b) Half left

(c) Half right

(d) Half up

(e) Half bottom

(f) Central Region

(g) Central Region

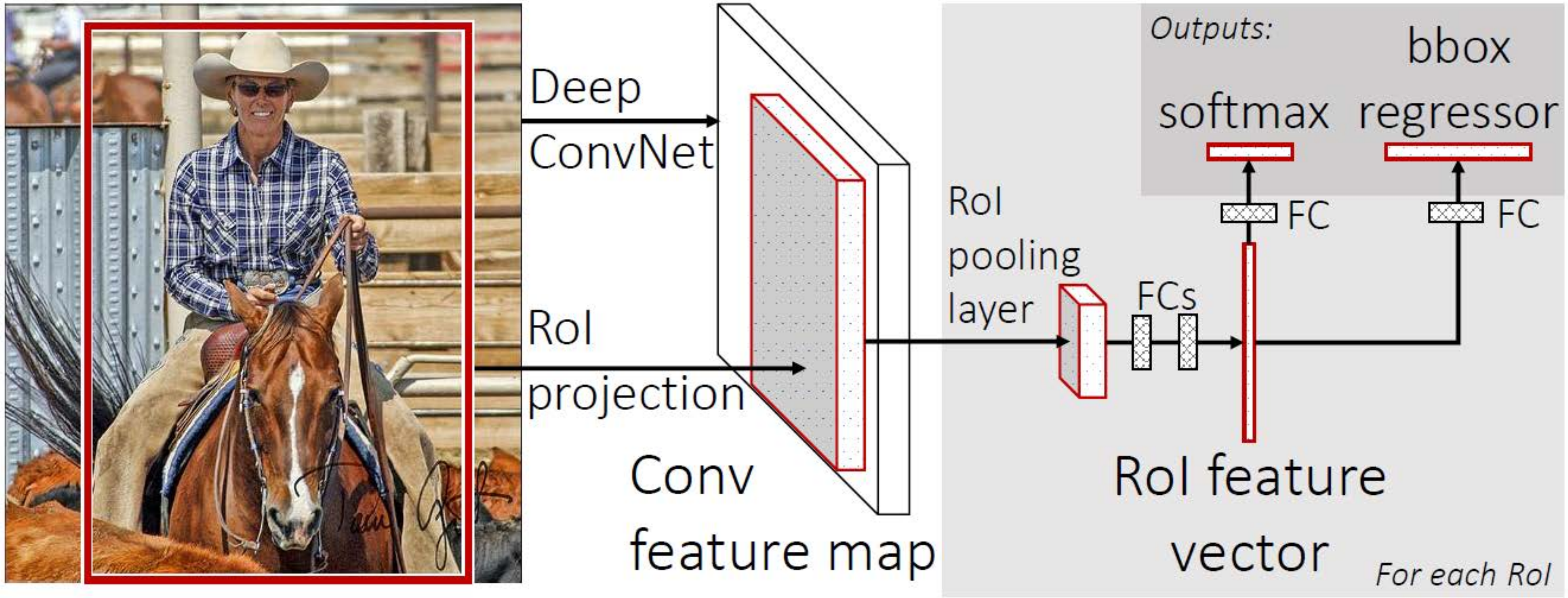
(h) Border Region

(i) Border Region

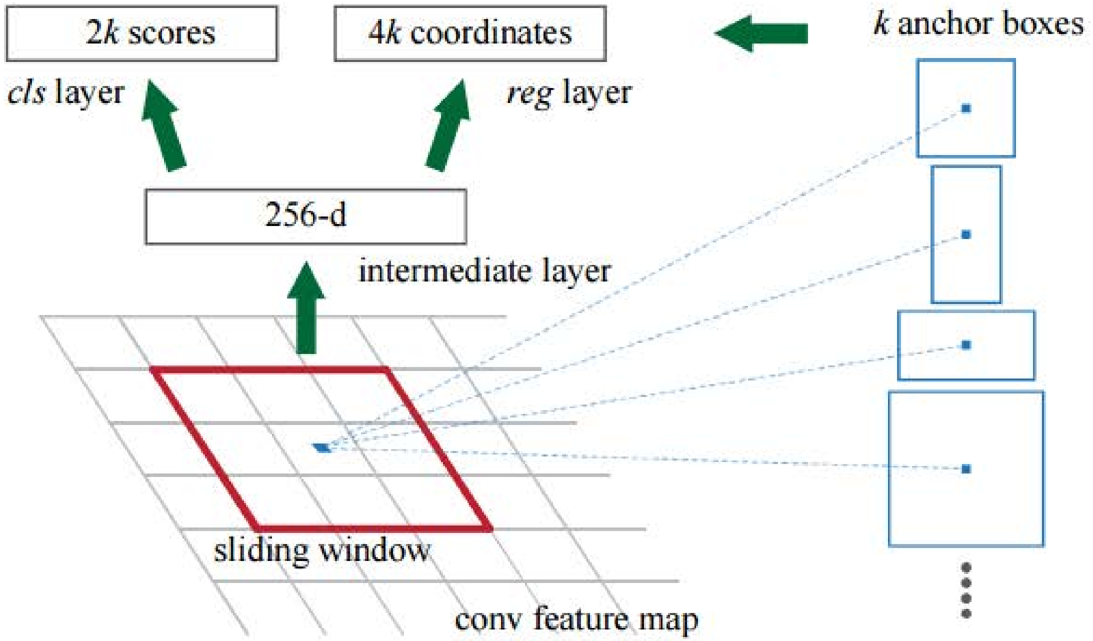
(j) Context. Region

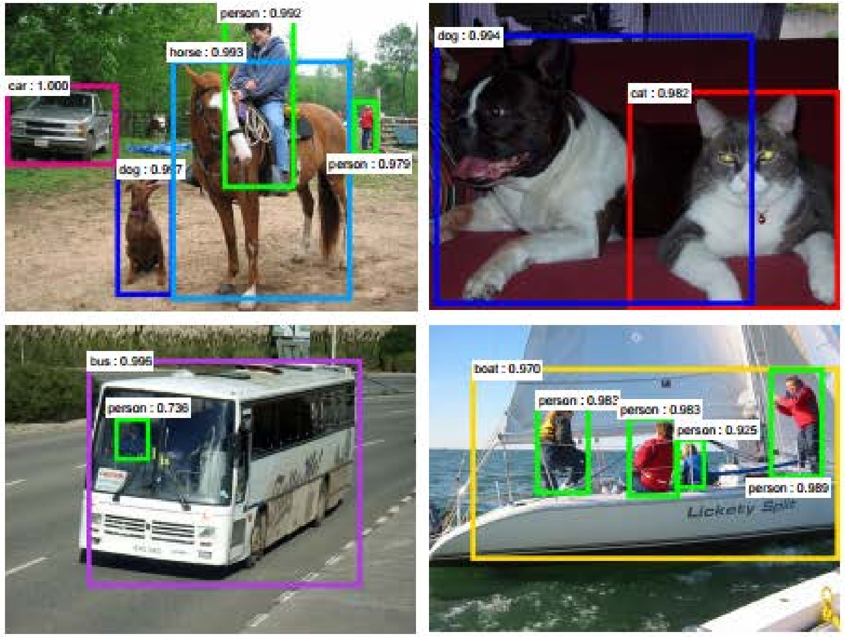
Spyros Gidaris, Nikos Komodakis, Object detection via a multi-region & semantic segmentation-aware CNN model

Fast RCNN


Deep
ConvNet
RoI
projection
Conv
feature map
RoI
pooling
layer
FCs
Outputs:
softmax
bbox
regressor
FC
FC
RoI feature
vector
For each RoI

Faster RCNN

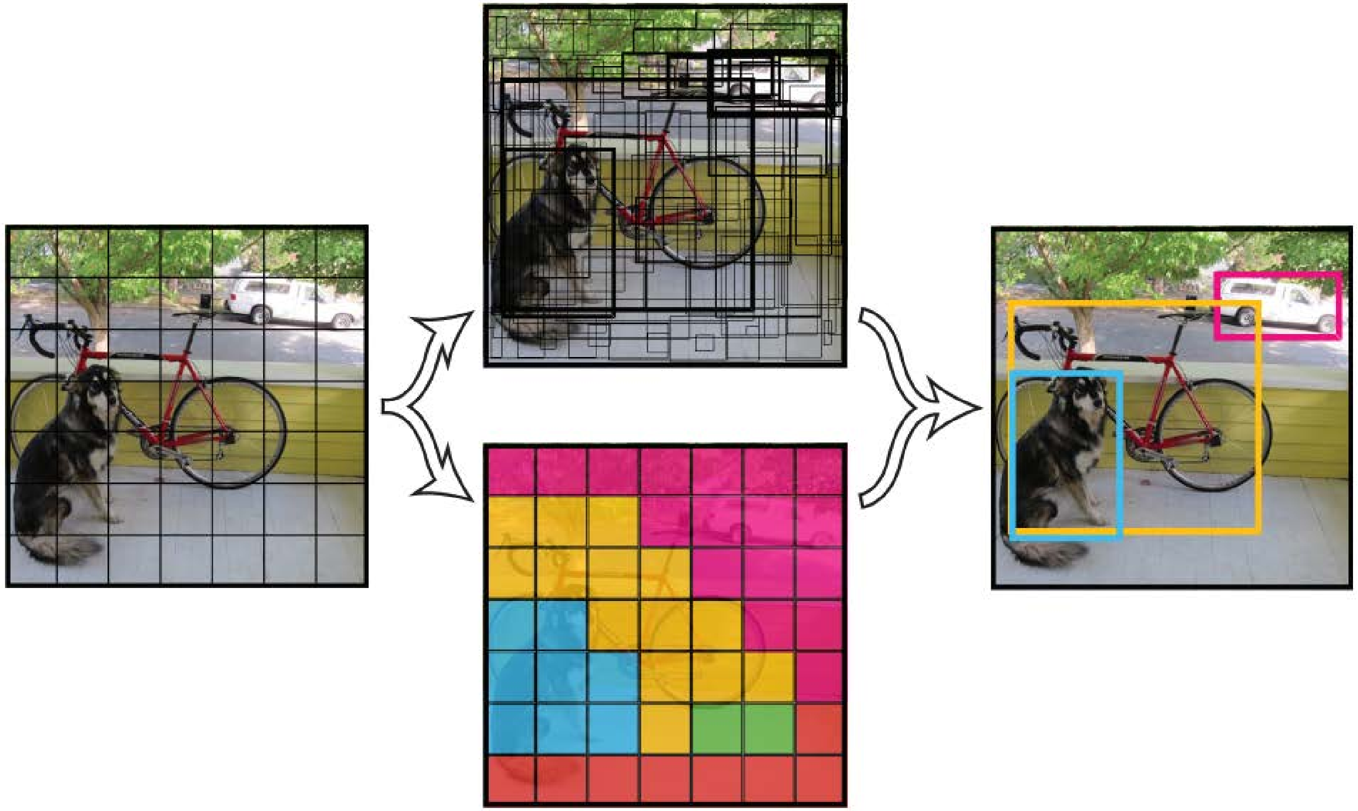




S. Ren, K. He, R. Girshick, and J. Sun. Faster r-cnn: Towards real-time object detection with region proposal networks.

YOLO

- More improved CNN based Object Detector:



Joseph Redmon, Santosh Divvala, Ross Girshick, Ali Farhadi, You Only Look Once: Unified, Real-Time Object Detection

Performance Comparison

- State-of-the-art methods comparison:

Method	ROI needed?	Regression?	Accuracy	Speed
RCNN	Y	N	62.4	0.01 fps
Fast-RCNN	Y	Y	68.4	0.01 fps
Faster-RCNN	N	Y	70.4	3 fps
YOLO	N	Y	57.9	45 fps

Joseph Redmon, Santosh Divvala, Ross Girshick, Ali Farhadi, You Only Look Once: Unified, Real-Time Object Detection

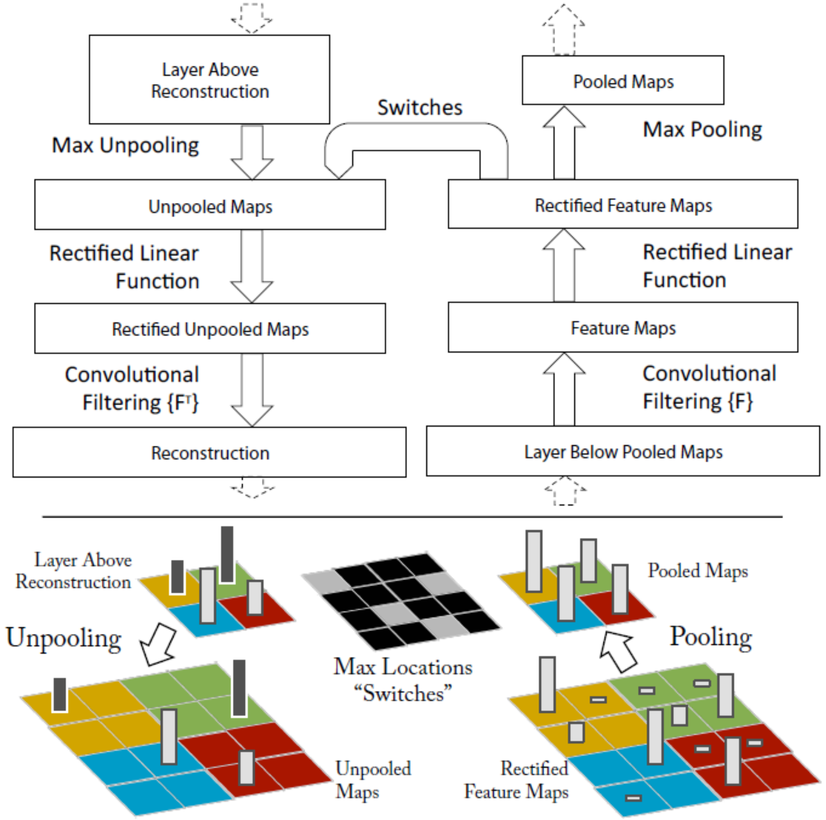
Comments

- Alex Net was the first one proposed for object detection
- Recent publications have focused on two aspects:
  - Fine-tuning for better region proposals, which serve as a critical pre-processing step for DNN
  - Seeking more applications
- Both hardware and software are accessible to the public
- However, no labeled training data are accessible to the public
- It can be implemented in the cloud platform, but not in the embedded system platform

Visualization of Deep Features

Feature Visualization

- De-conv Network:



Features at Lower Layers

- Conv1 Filter Response (Gabor-like filters)

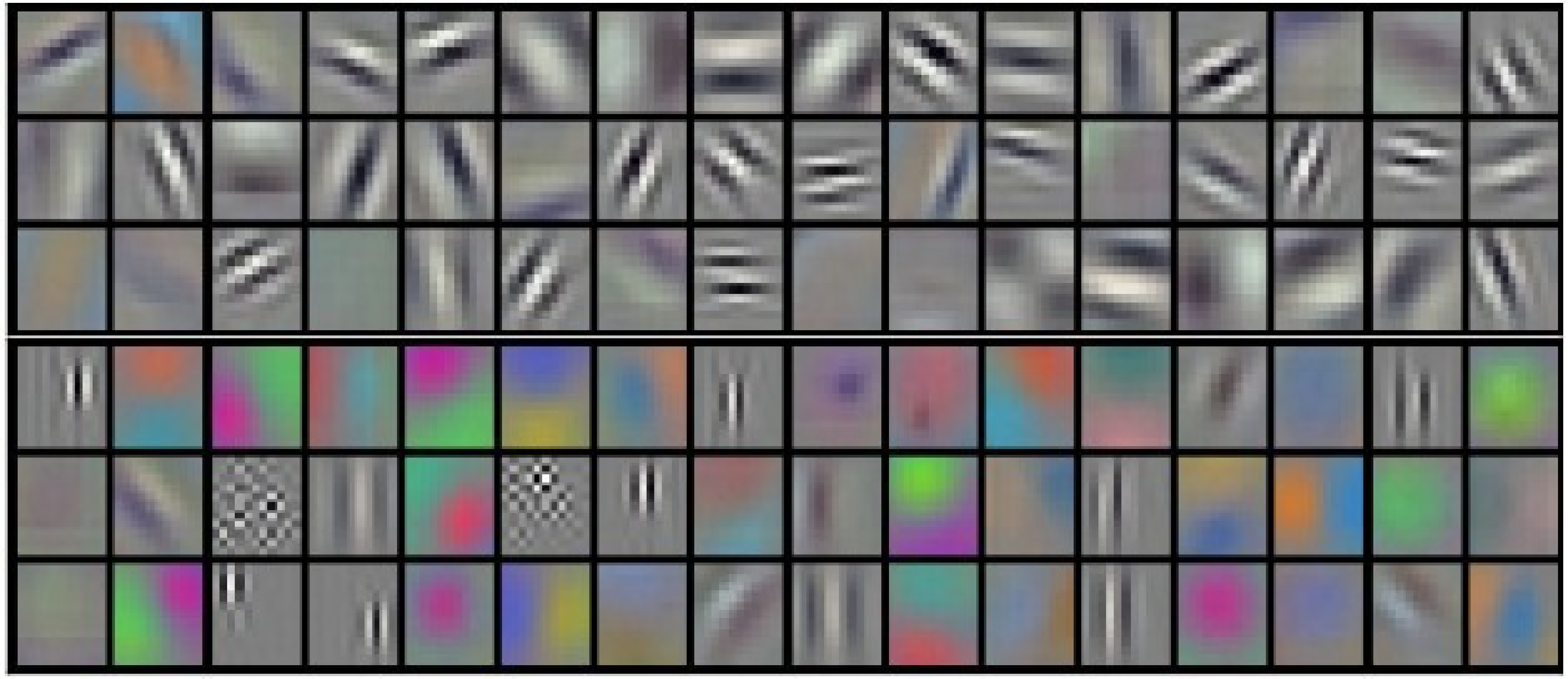
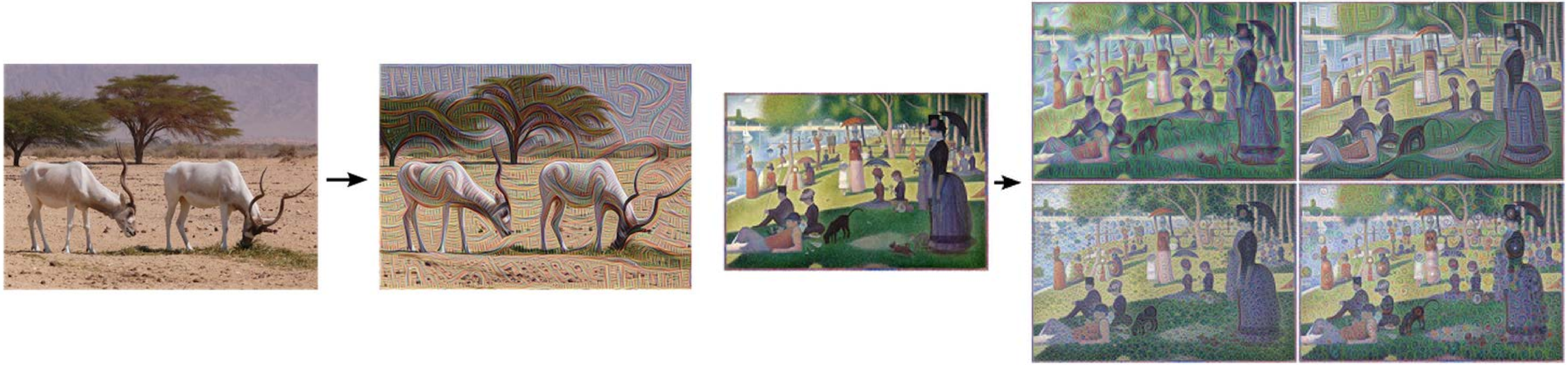


Figure Credit: Stanford CS231n Course Instruction

Reconstruction at Lower Layers

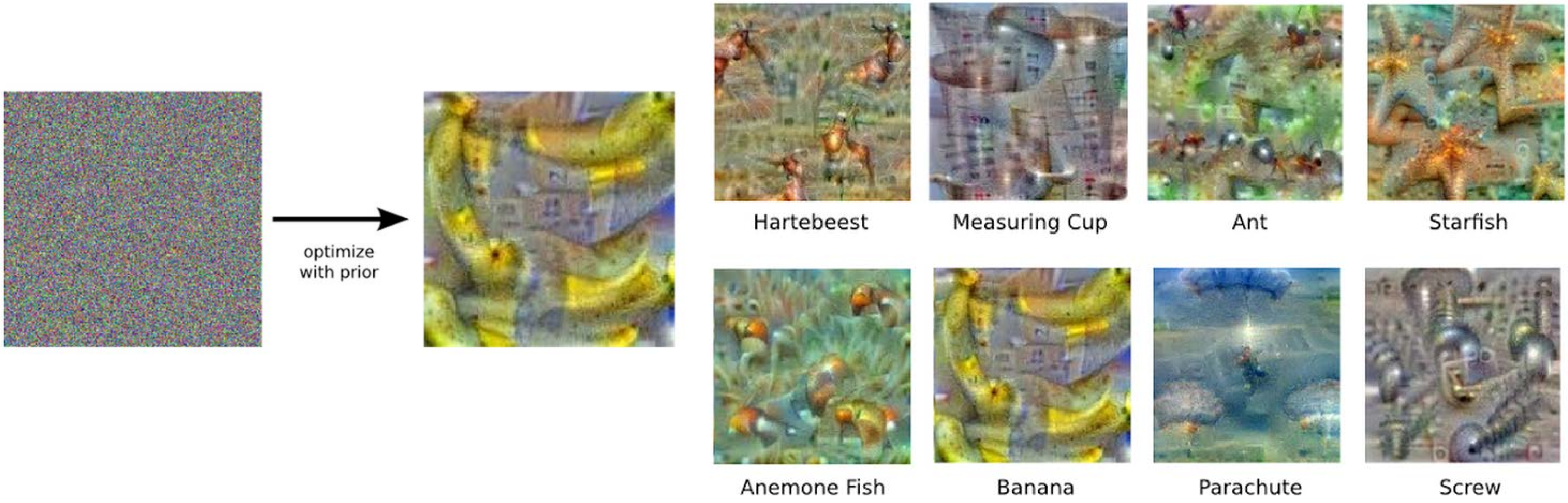
- Extracting low level features (oriented edges/contours)



http://googleresearch.blogspot.ch/2015/06/inceptionism-going-deeper-into-neural.html

Reconstruction at Higher Layers

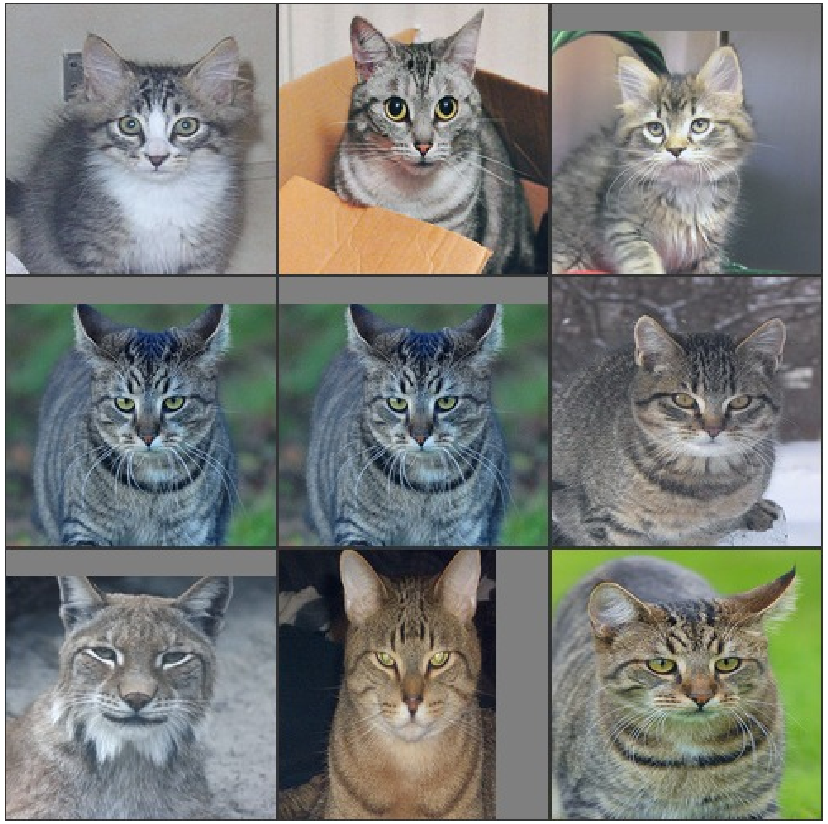
- Random Noise Input



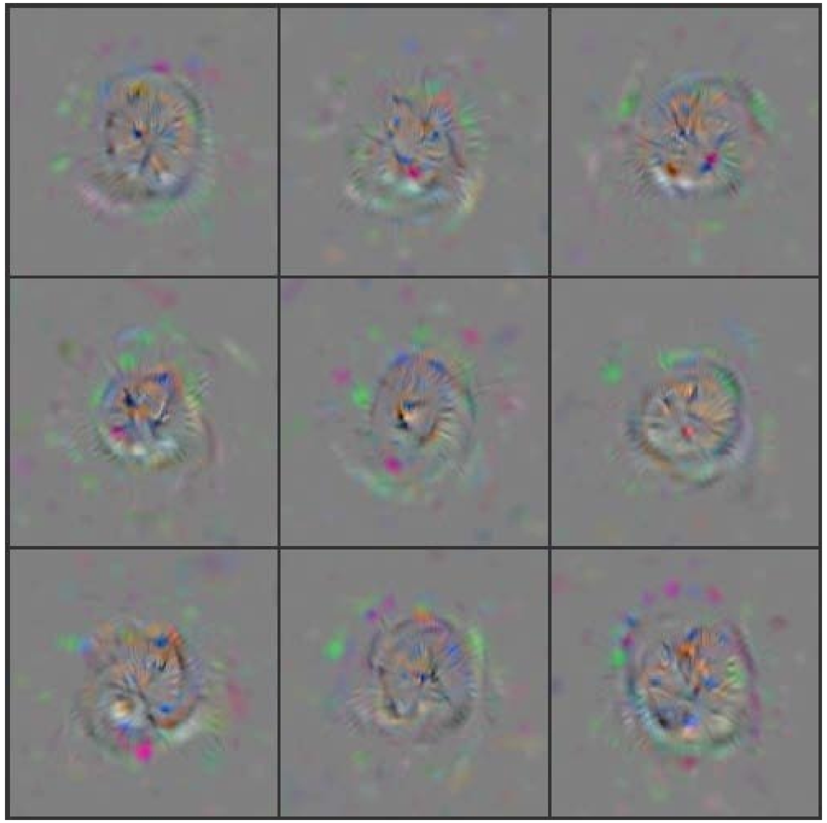
http://googleresearch.blogspot.ch/2015/06/inceptionism-going-deeper-into-neural.html

Deep Features at Conv5

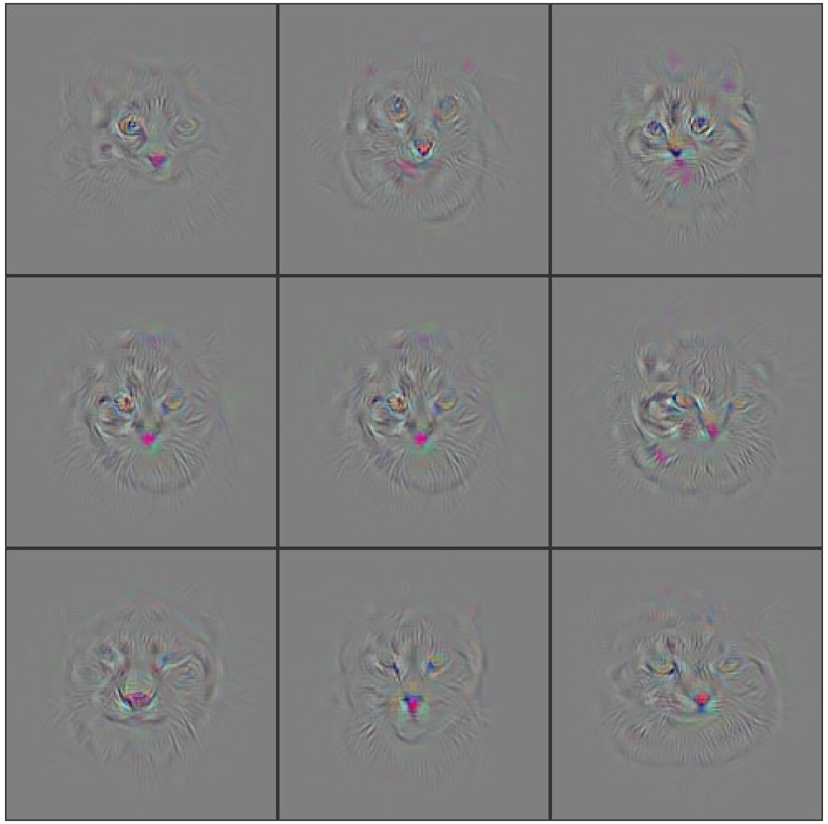
- Cat Face Filter Example (Filter 111 in the Yos-CaffeNet Model):



Top 9 Input Activation Images



Max Reconstructed Input Activation



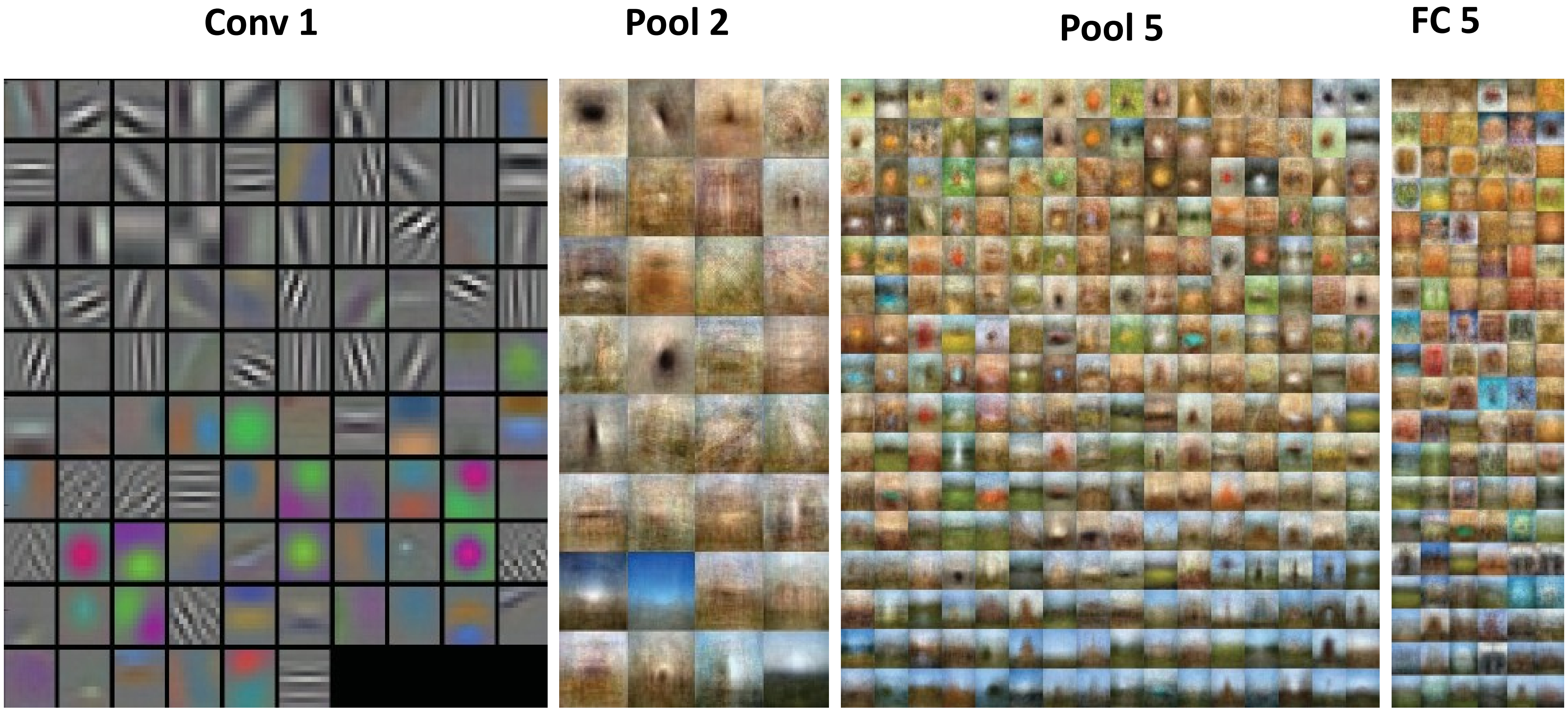
Deconv Image

Images are generated from Deep-VIS Toolbox

Comments

- Deep feature visualization provides helpful insight into the role played by various layers
  - Lower layers – subband-filtered images with large coverage
  - Higher layers – contour-dominating images with focused coverage
  - Three general trends
    - Contour formation
      - From surfaces to contours
    - Color reduction
      - From colorful to colorless
    - Background removal
      - From larger regions (with background) to focused regions (without background)
- The whole process can be viewed as a spatial (contour) feature binding process

Deep Features for Scene Recognition

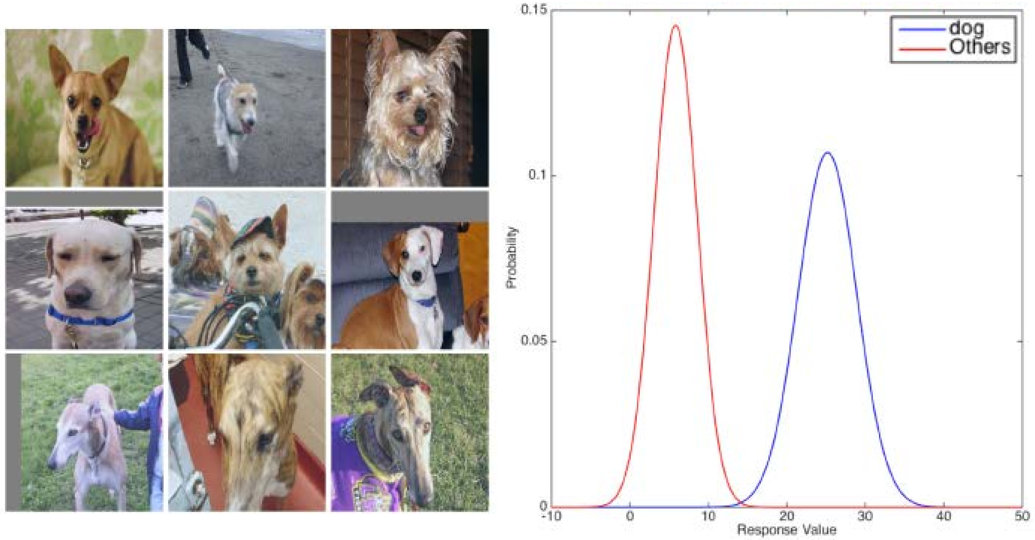


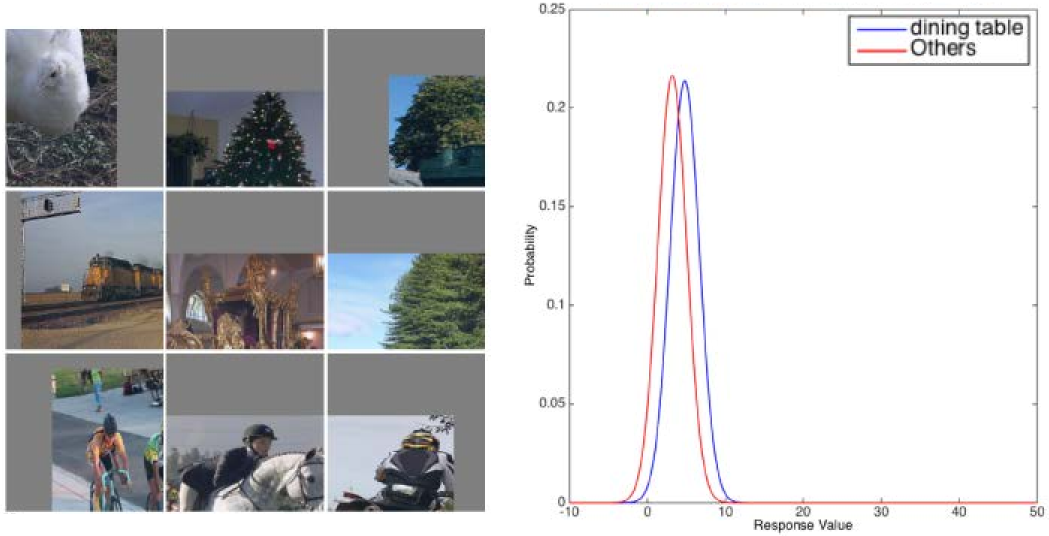
Zhou et al. “Learning deep features for scene recognition using places database”, NIPS 2014.

Gaussian Confusion Measure (GCM)

Conv5 Filter Response

- Gaussian Confusion Measure

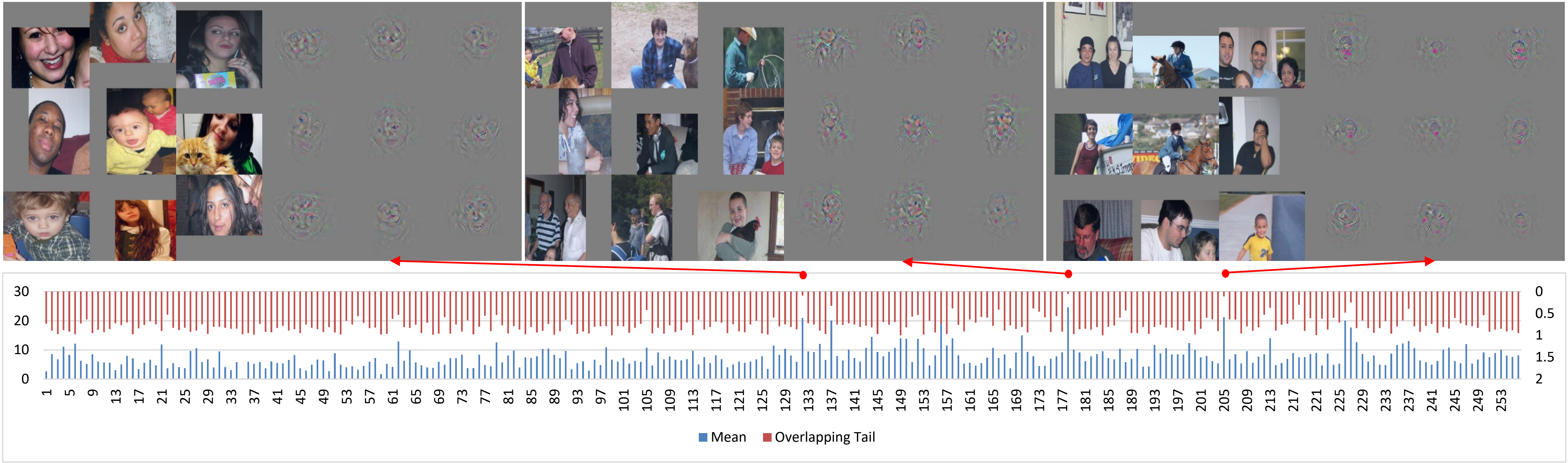




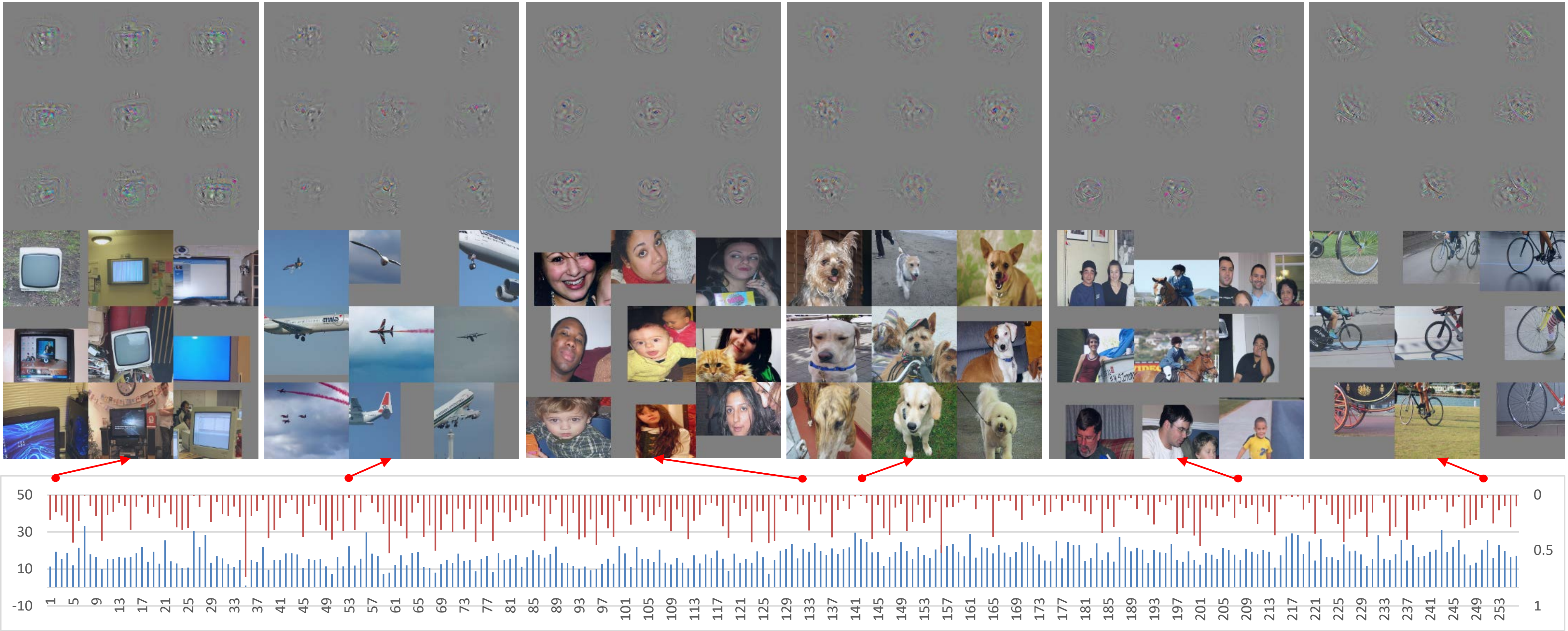
Detection Error and Mean of Conv5 Filter Responses

Responses w.r.t. human objects

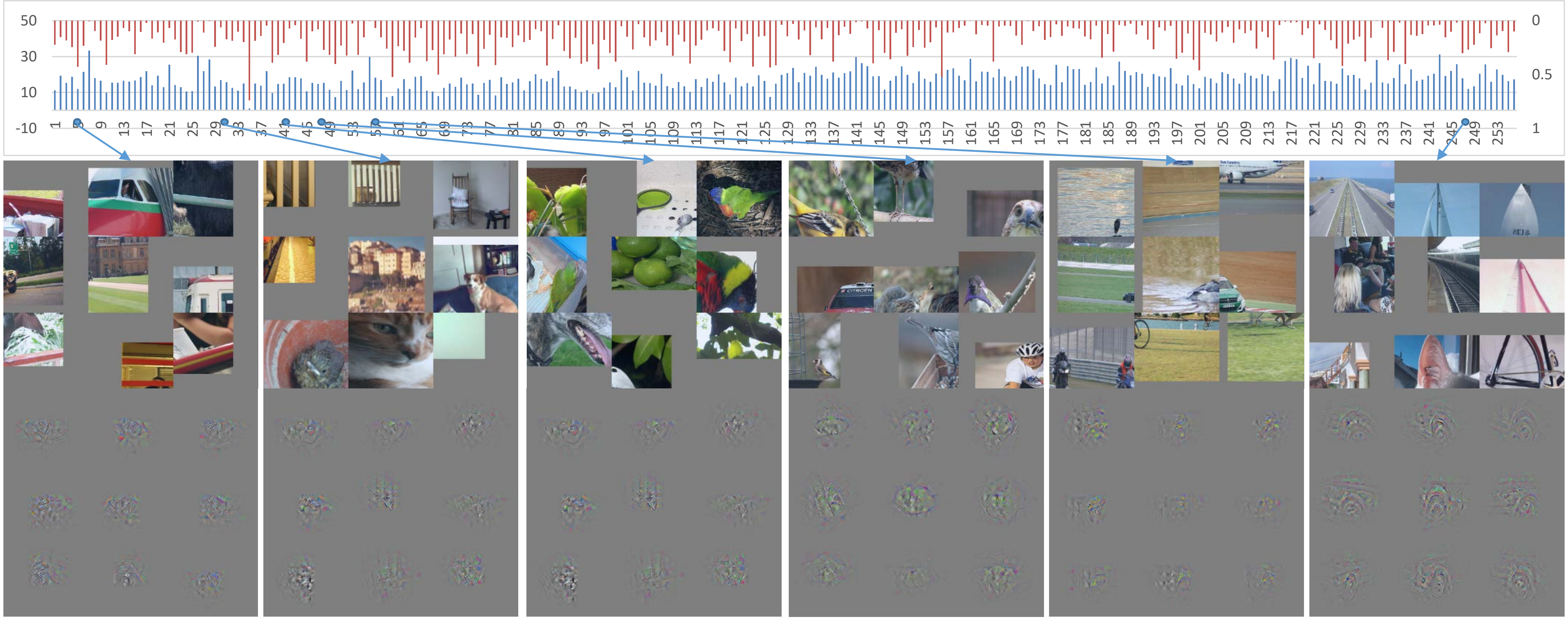
-- Known as “Grandmother Cell (GMC)” like features for human objects



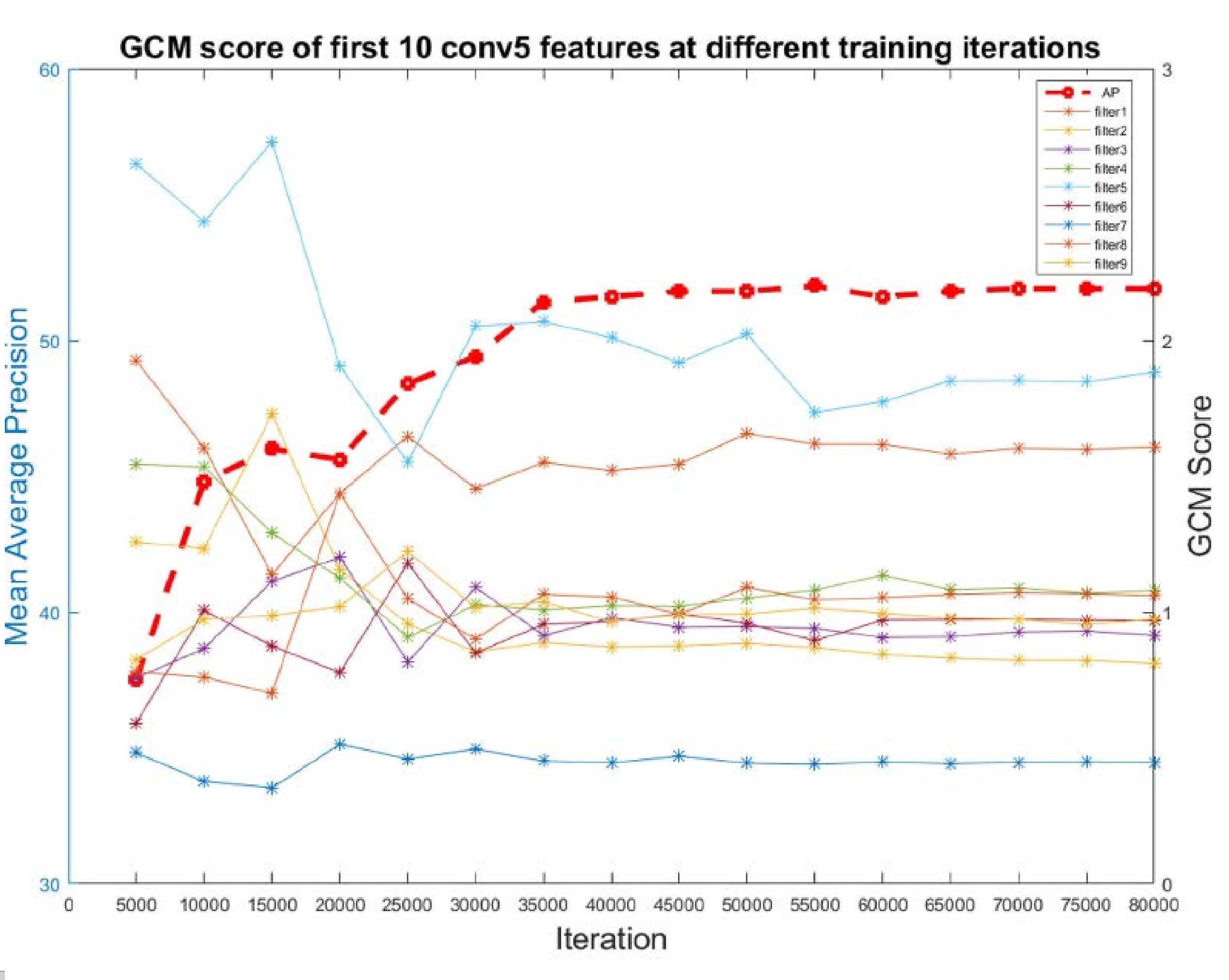
Optimal Conv5 Filters Against Multiple Object Classes (Good Examples)



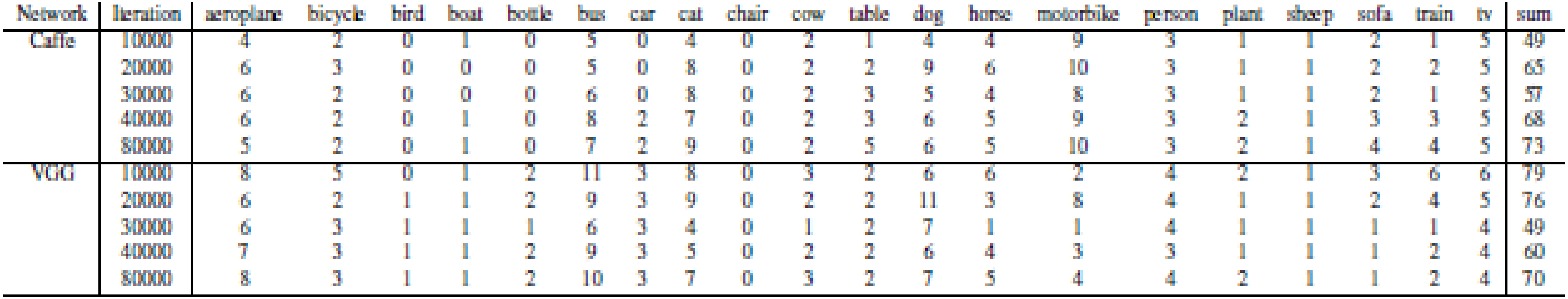
Optimal Conv5 Filters Against Multiple Object Classes (Bad Examples)



GCM Scores of Top 10 Conv5 Features versus Iteration Number



Number of GMC-like Features versus Iteration Number

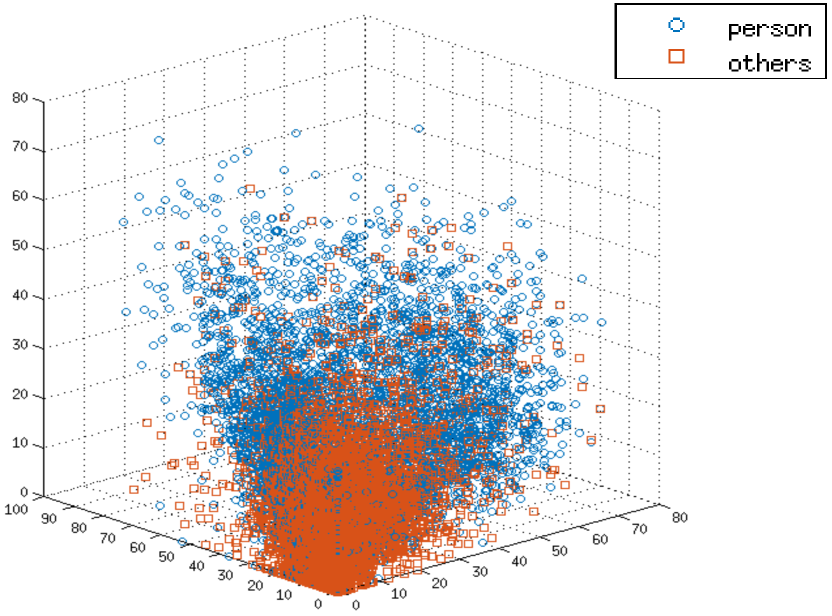


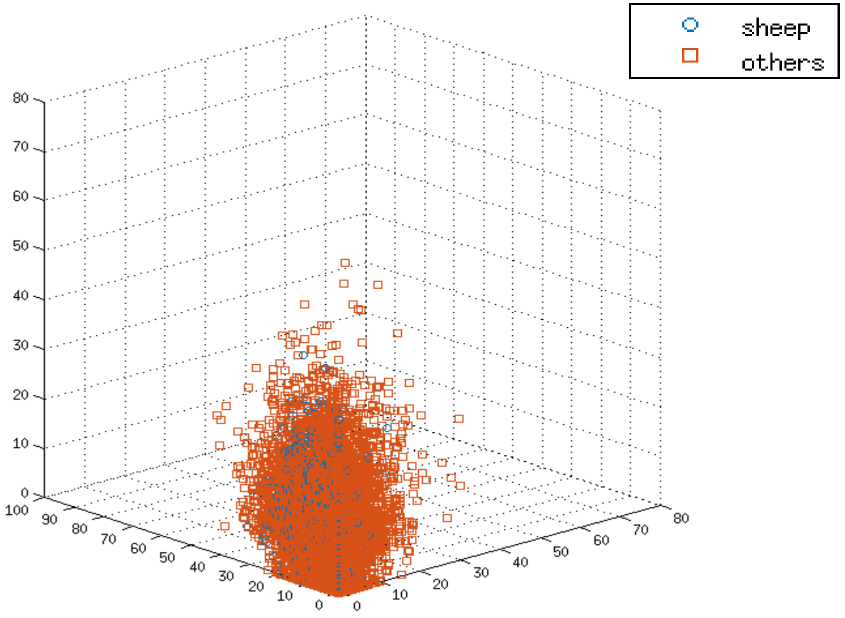
Network	Iteration	aeroplane	bicycle	bird	boat	bottle	bus	car	cat	chair	cow	table	dog	horse	motorbike	person	plant	sheep	sofa	train	tv	sum
Caffe	10000	4	2	0	1	0	5	0	4	0	2	1	4	4	9	3	1	1	2	1	5	49
	20000	6	3	0	0	0	5	0	8	0	2	2	9	6	10	3	1	1	2	2	5	65
	30000	6	2	0	0	0	6	0	8	0	2	3	5	4	8	3	1	1	2	1	5	57
	40000	6	2	0	1	0	8	2	7	0	2	3	6	5	9	3	2	1	3	3	5	68
	80000	5	2	0	1	0	7	2	9	0	2	5	6	5	10	3	2	1	4	4	5	73
VGG	10000	8	5	0	1	2	11	3	8	0	3	2	6	6	2	4	2	1	3	6	6	79
	20000	6	2	1	1	2	9	3	9	0	2	2	11	3	8	4	1	1	2	4	5	76
	30000	6	3	1	1	1	6	3	4	0	1	2	7	1	1	4	1	1	1	1	4	49
	40000	7	3	1	1	2	9	3	5	0	2	2	6	4	3	3	1	1	1	2	4	60
	80000	8	3	1	1	2	10	3	7	0	3	2	7	5	4	4	2	1	1	2	4	70

Cluster Purity Measure (CPM)

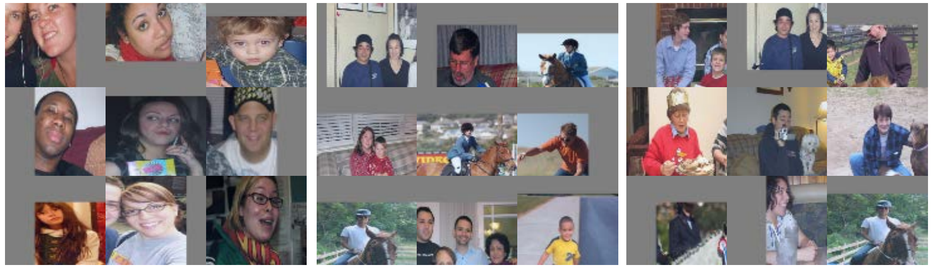
Examples of Cluster Purity Measure (1)

Good



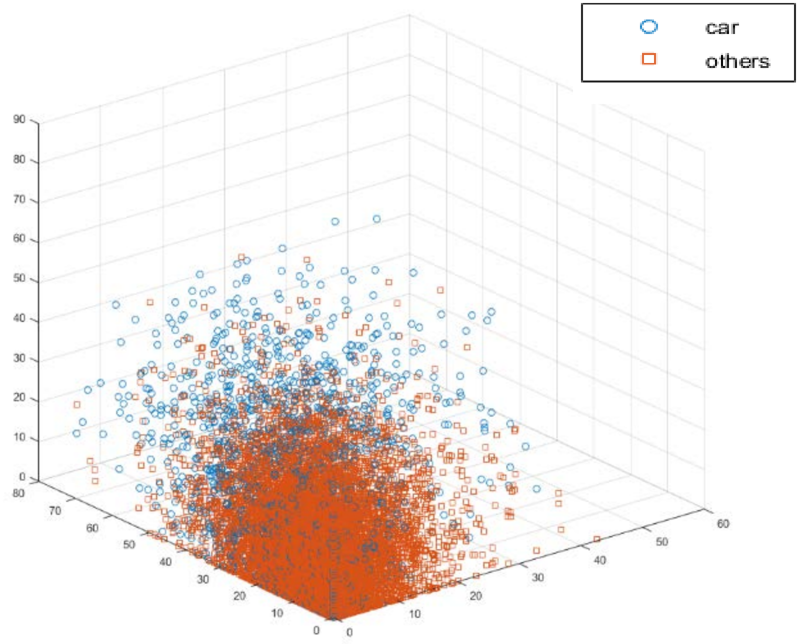


Poor

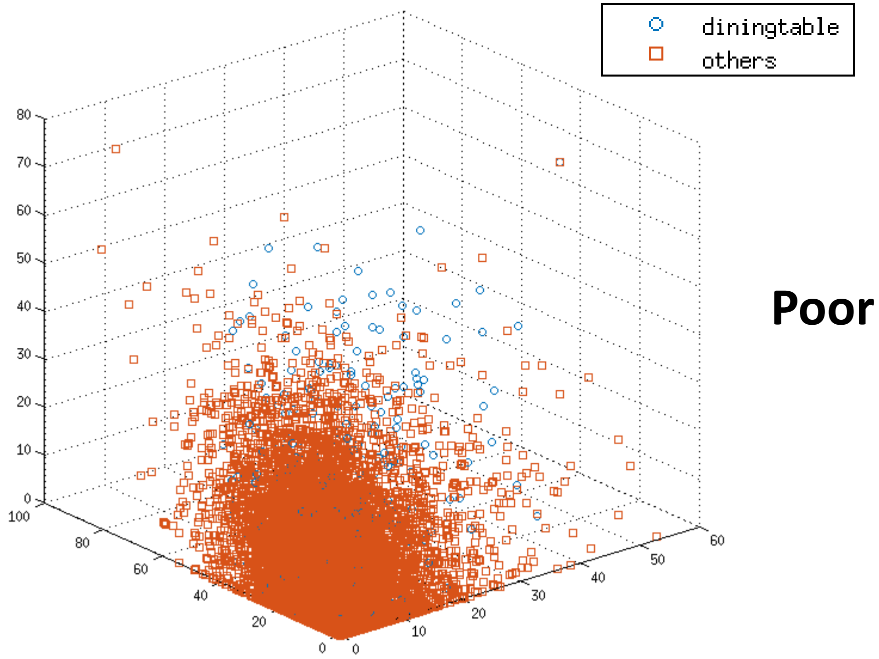


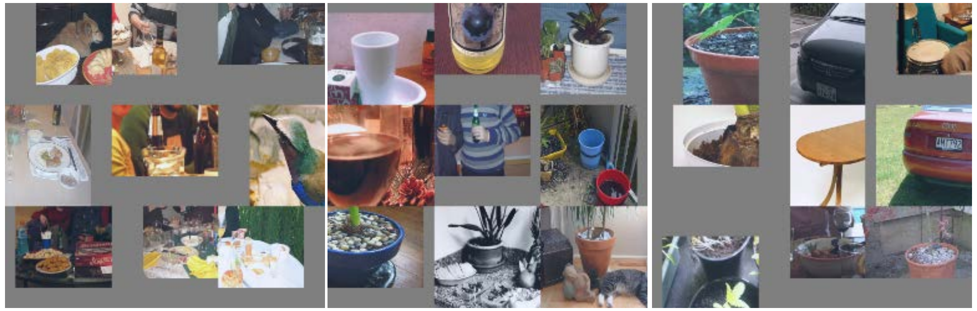
Examples of Cluster Purity Measure (2)

Good



Poor





Comments

- Besides feature visualization, we can quantify the power of a particular filter in discriminating an object class
    - 1-D case case: A smaller “Gaussian Confusion Measure (GCM)”
    - Multiple-Dimensional case: A higher “Cluster Purity Measure (CPM)”
- GCM works for a class of objects with a similar setting
- CPM works for a class of objects with multiple settings