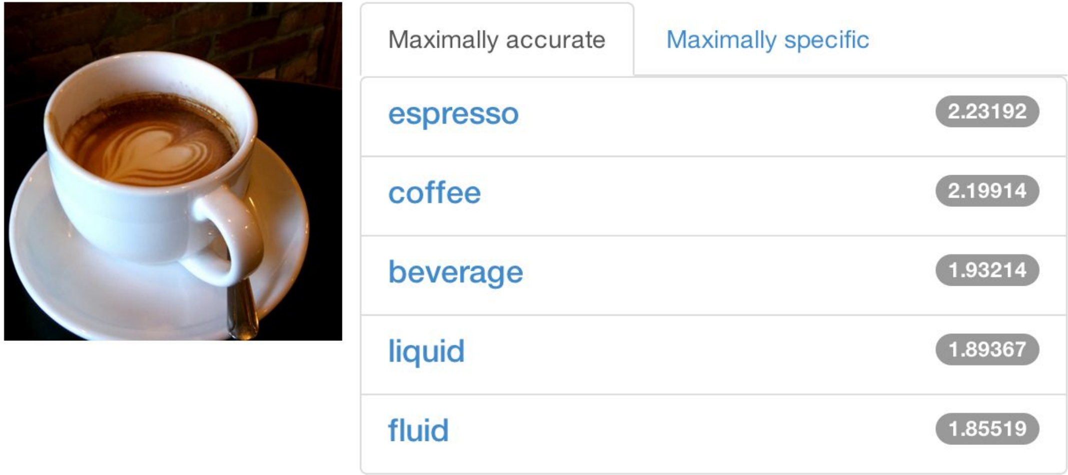


Maximally accurate | Maximally specific

espresso	2.23192
coffee	2.19914
beverage	1.93214
liquid	1.89367
fluid	1.85519

Brewing Deep Networks With Caffe

Yangqing Jia

Look for
additional notes
for the slides

What is, and Why Caffe?

- Pure C++/CUDA Implementation
- Fast, well-tested code
- Tools, demos, and recipes
- Seamless switch between CPU and GPU
    - `Caffe::set_mode(Caffe::GPU);`

Prototype

Training

Deployment

Statistics...

- Speed with Krizhevsky's 2012 model:
  - K40 / Titan: 2 ms/image, K20: 2.6ms
  - (40 million images / day)
  - 8-core CPU: ~20 ms/image
- ~ 8K lines of C/C++ code
  - with unit test: ~14k

● C++ 84.4% ● Python 10.7% ● Cuda 3.5% ● Other 1.4%

* Not counting image I/O time. Details at http://caffe.berkeleyvision.org/performance_hardware.html

Do I want Caffe If I...

- Have small or medium scale applications?
  - Scripting languages may save engineering time indeed.

- Prefer simpler scripting languages?
  - We now provide Python and Matlab wrappers.

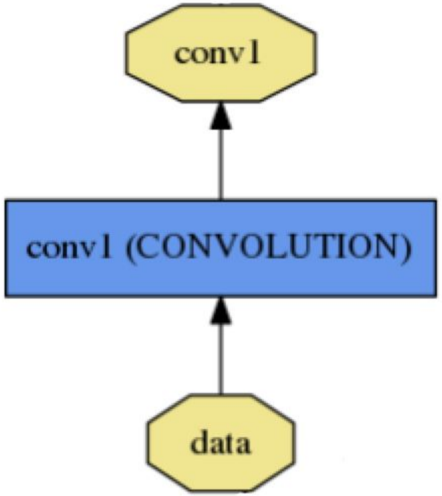
- Hate tricky compilation issues?
  - Recipes on Caffe webpage, and github.
  - Virtualbox / EC2 images to be provided soon.

A Caffe Layer

```
name: "conv1"
type: CONVOLUTION
bottom: "data"
top: "conv1"
convolution_param {
    num_output: 20
    kernel_size: 5
    stride: 1
    weight_filler {
        type: "xavier"
    }
}
```

name, type, and the connection structure (input blobs and output blobs)

layer-specific parameters

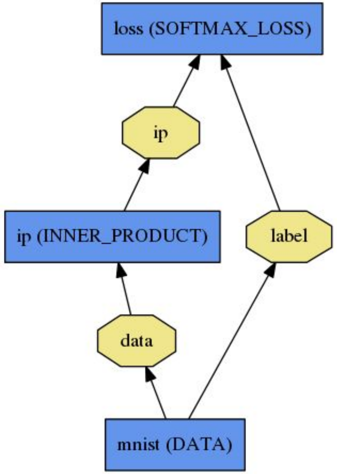


*Link to the Google Protobuffer Documentation

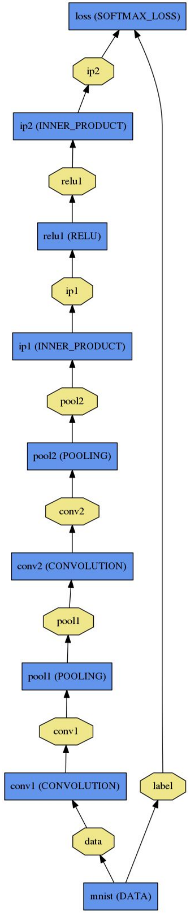
A Caffe Network

- A network is a set of layers connected as a DAG:

```
name: "dummy-net"
layers { name: "data" …}
layers { name: "conv" …}
layers { name: "pool" …}
     … more layers …
layers { name: "loss" …}
```

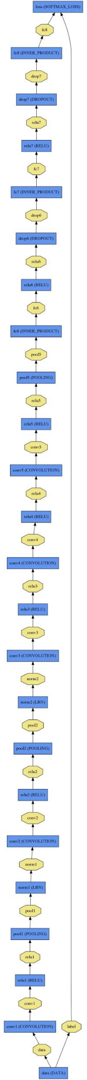


LogReg ↑



LeNet ⟶

ImageNet, Krizhevsky 2012 ⟶



Training a Caffe Net

Write a solver protobuffer:

```
train_net: "lenet_train.prototxt"
base_lr: 0.01
momentum: 0.9
weight_decay: 0.0005
max_iter: 10000
snapshot_prefix: "lenet_snapshot"
solver_mode: GPU
```

All you need to run things on the GPU.

End to End Recipe...

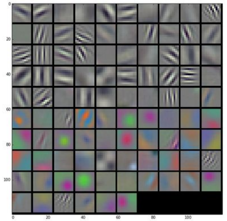
- Convert the data to Caffe-format
  - leveldb, hdf5/.mat, list of images, LMDB, etc.
- Write a Network Definition
- Write a Solver Protobuffer text
- Train with the provided train_net tool
  - build/tools/train_net.bin solver.prototxt

- Examples are your friends
  - `caffe/examples/mnist,cifar10,imagenet`
  - `caffe/tools/*.bin`

Peeking into Networks

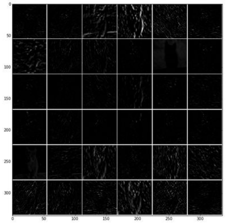
The first layer filters, conv1

```
In [8]: # the parameters are a list of [weights, biases]
        filters = net.params['conv1'][0].data
        vis_square(filters.transpose(0, 2, 3, 1))
```

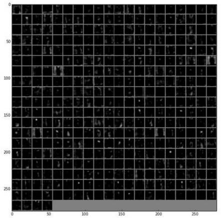


The first layer output, conv1 (rectified responses of the filters above, first 36 only)

```
In [9]: feat = net.blobs['conv1'].data[4, :36]
        vis_square(feat, padval=1)
```

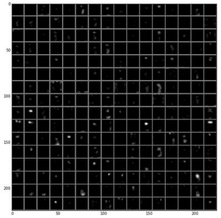


```
In [13]: feat = net.blobs['conv4'].data[4]
         vis_square(feat, padval=0.5)
```



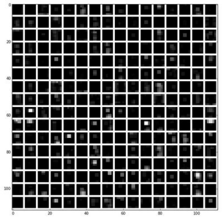
The fifth layer output, conv5 (rectified, all 256 channels)

```
In [14]: feat = net.blobs['conv5'].data[4]
         vis_square(feat, padval=0.5)
```

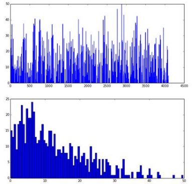


The fifth layer after pooling, pool5

```
In [15]: feat = net.blobs['pool5'].data[4]
         vis_square(feat, padval=1)
```

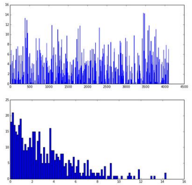


```
In [16]: feat = net.blobs['fc6'].data[4]
         plt.subplot(2, 1, 1)
         plt.plot(feat.flat)
         plt.subplot(2, 1, 2)
         _ = plt.hist(feat.flat[feat.flat > 0], bins=100)
```

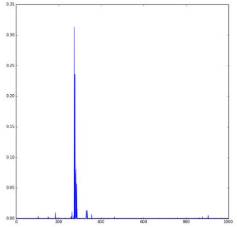


The second fully connected layer, fc7 (rectified)

```
In [17]: feat = net.blobs['fc7'].data[4]
         plt.subplot(2, 1, 1)
         plt.plot(feat.flat)
         plt.subplot(2, 1, 2)
         _ = plt.hist(feat.flat[feat.flat > 0], bins=100)
```



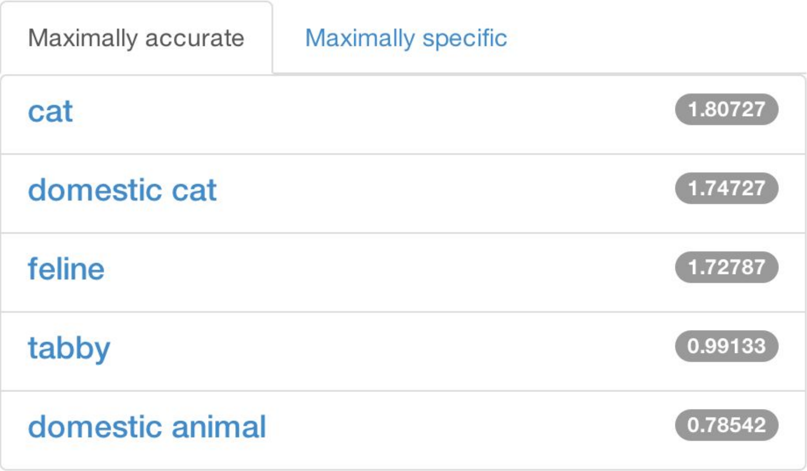
```
In [18]: feat = net.blobs['prob'].data[4]
         plt.plot(feat.flat)

Out[18]: [<matplotlib.lines.Line2D at 0x12b260710>]
```



A Quick Sip of Brewed Models

http://demo.caffe.berkeleyvision.org/

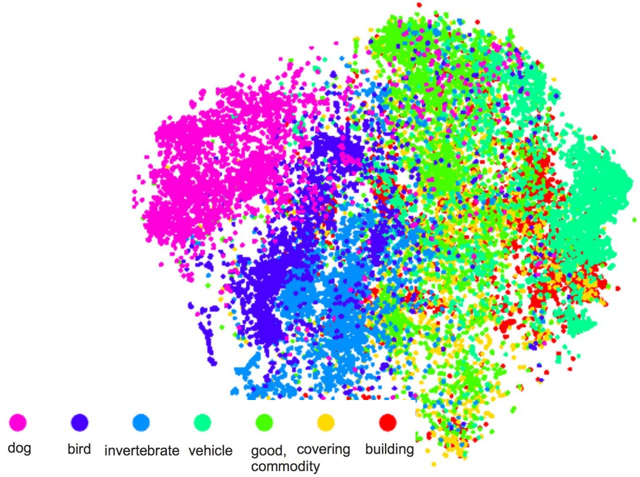
(demo code to be open-sourced soon)



cat	1.80727
domestic cat	1.74727
feline	1.72787
tabby	0.99133
domestic animal	0.78542

Transfer Learned Knowledge

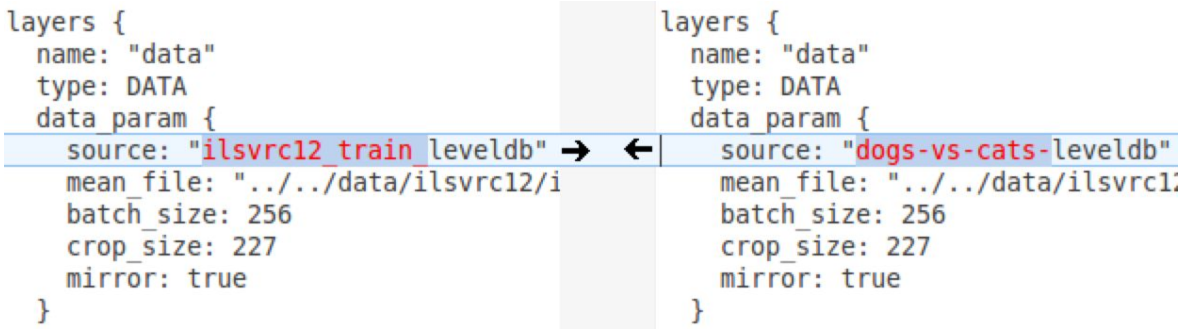
- Taking a pre-trained model and finetune it for related tasks [Zeiler-Fergus] [DeCAF] [OverFeat]



*Dog and cat image Copyright kaggle.com

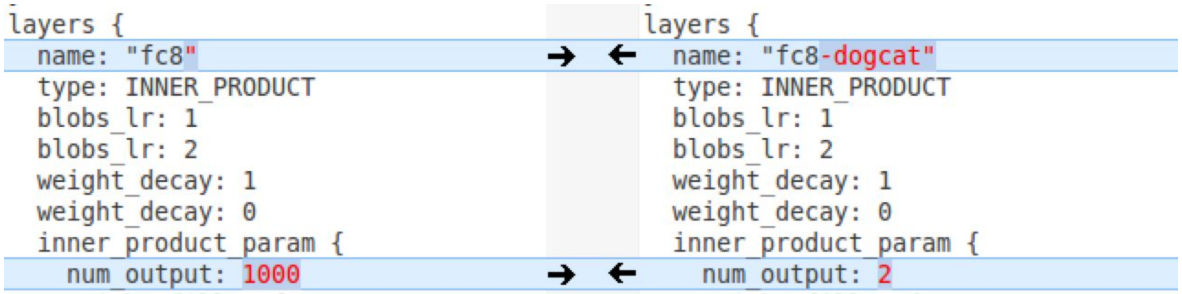
Dogs vs Cats: top 10% in 10 minutes

- Simply change a few lines in the layer definition



```
layers {                                          layers {
  name: "data"                                      name: "data"
  type: DATA                                        type: DATA
  data_param {                                      data_param {
    source: "ilsvrc12_train_leveldb" →     ←        source: "dogs-vs-cats-leveldb"
    mean_file: "../../data/ilsvrc12/i               mean_file: "../../data/ilsvrc1
    batch_size: 256                                 batch_size: 256
    crop_size: 227                                  crop_size: 227
    mirror: true                                    mirror: true
  }                                                 }
```

Input:
A different source



```
layers {                                          layers {
  name: "fc8"                      →     ←        name: "fc8-dogcat"
  type: INNER_PRODUCT                               type: INNER_PRODUCT
  blobs_lr: 1                                       blobs_lr: 1
  blobs_lr: 2                                       blobs_lr: 2
  weight_decay: 1                                   weight_decay: 1
  weight_decay: 0                                   weight_decay: 0
  inner_product_param {                             inner_product_param {
    num_output: 1000               →     ←            num_output: 2
```

Last Layer:
A different classifier

Dogs vs Cats: top 10% in 10 minutes

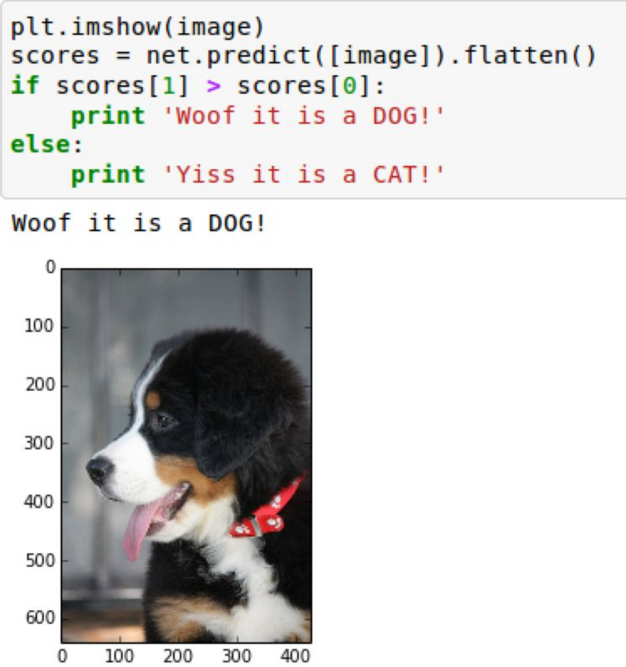
```
build/tools/finetune_net.bin dogcat_solver.prototxt pretrained_imagenet_model
```

Under the hood (loosely speaking):

```
net = new Caffe::Net(
    "dogcat_solver.prototxt");
net.CopyTrainedNetFrom(
    pretrained_model);
solver.Solve(net);
```

Example code to be made available at

caffe/examples/dogs-vs-cats/



```
plt.imshow(image)
scores = net.predict([image]).flatten()
if scores[1] > scores[0]:
    print 'Woof it is a DOG!'
else:
    print 'Yiss it is a CAT!'
```

```
Woof it is a DOG!
```

Object Detection

R-CNN: Regions with Convolutional Neural Networks

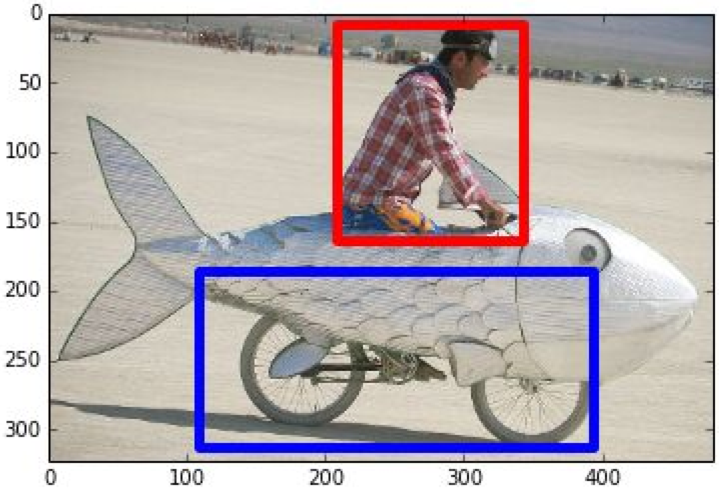
http://nbviewer.ipython.org/github/BVLC/caffe/blob/dev/examples/detection.ipynb

Full R-CNN scripts available at

https://github.com/rbgirshick/rcnn

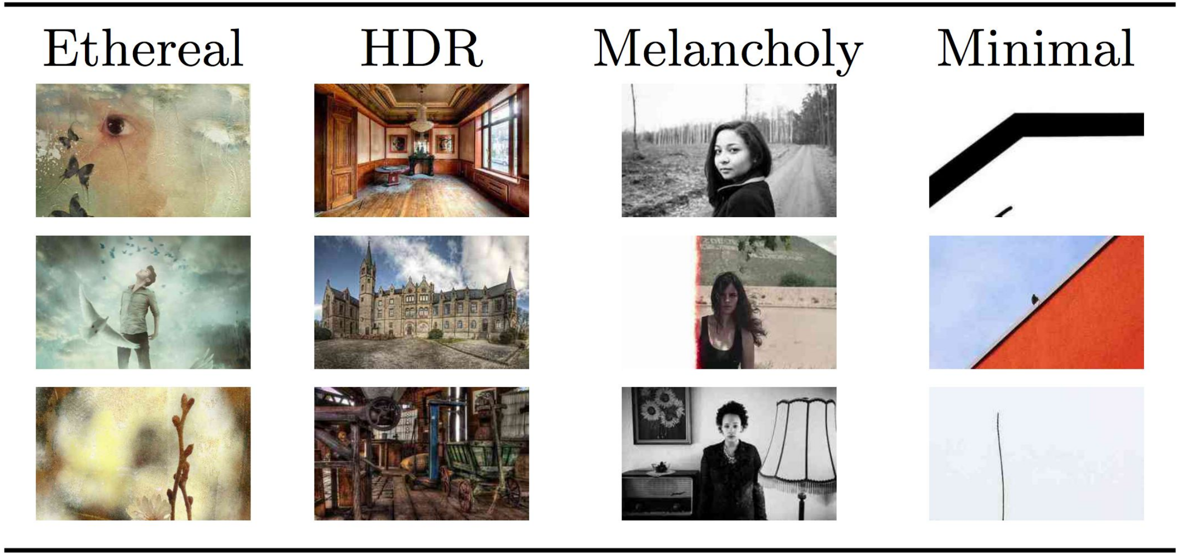
Ross Girshick et al.
Rich feature hierarchies for accurate object detection and semantic segmentation

Oral Session 2A, Tue 1:30 pm



Visual Style Recognition

Sergey Karayev, http://vislab.berkeleyvision.org/, demo available online



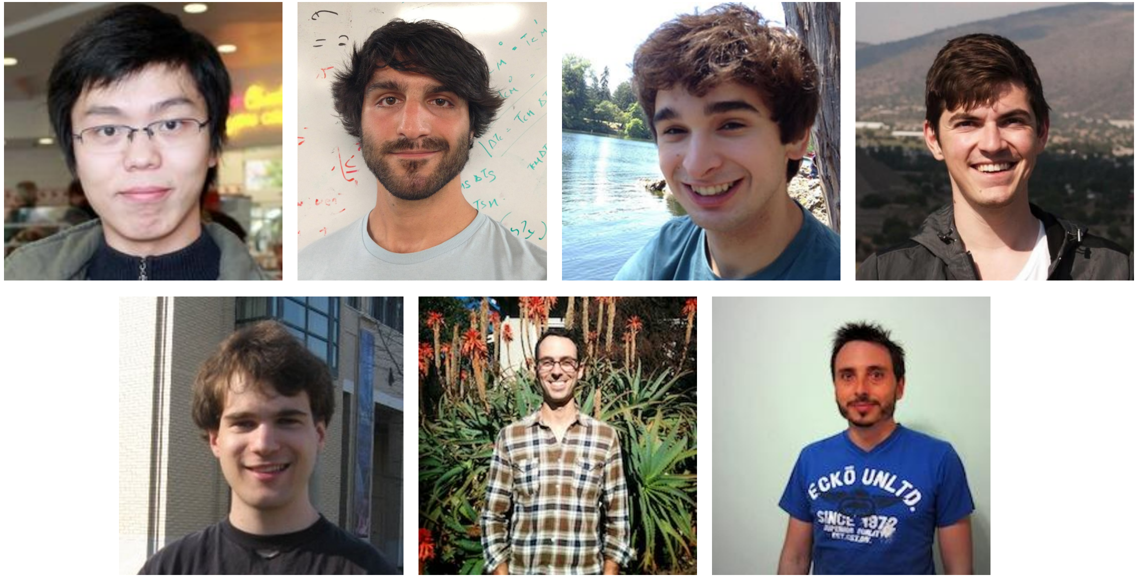
Other Styles:

Vintage
Long Exposure
Noir
Pastel
Macro
… and so on.

In One Sip

Caffe...

- is C++/CUDA friendly
- is fast
- is state-of-the-art
- has tips, recipes, demos
- all available under an open-source initiative



Yangqing Jia, Evan Shelhamer, Jeff Donahue, Sergey Karayev
Jonathan Long, Ross Girshick, Sergio Guadarrama

https://github.com/UCB-ICSI-Vision-Group/caffe-paper/raw/arxiv/caffe.pdf