Getting started with Caffe

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Agenda

- Caffe tour
  - Overview
  - Example applications
  - Setup
  - Performance
- Hands-on lab preview

A tour of Caffe

What is Caffe?

An open framework for deep learning developed by the Berkeley Vision and Learning Center (BVLC)

caffe.berkeleyvision.org
http://github.com/BVLC/caffe

- Pure C++/CUDA architecture
- Command line, Python, MATLAB interfaces
- Fast, well-tested code
- Pre-processing and deployment tools, reference models and examples
- Image data management
- Seamless GPU acceleration
- Large community of contributors to the open-source project

What is Caffe?

End-to-end Deep Learning for the practitioner and developer

Prototype

Train

Deploy

Caffe features

Data pre-processing and management

Data ingest formats

LevelDB or LMDB database

In-memory (C++ and Python only)

HDF5

Image files

Pre-processing tools

LevelDB/LMDB creation from raw images

Training and validation set creation with shuffling

Mean-image generation

```
$CAFFE_ROOT/build/tools
```

Data transformations

Image cropping, resizing, scaling and mirroring

Mean subtraction

Caffe features

Deep Learning model definition

- Protobuf model format
  - Strongly typed format
  - Human readable
  - Auto-generates and checks Caffe code
  - Developed by Google
  - Used to define network architecture and training parameters
  - No coding required!

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

Caffe features

Deep Learning model definition

- Loss functions:
  - **Classification**
    - Softmax
    - Hinge loss
  - **Linear regression**
    - Euclidean loss
  - **Attributes/multiclassification**
    - Sigmoid cross entropy loss
  - **and more…**
- Available layer types:
  - Convolution
  - Pooling
  - Normalization
- Activation functions:
  - ReLU
  - Sigmoid
  - Tanh
  - and more…

Caffe features

Deep Neural Network training

Network training also requires no coding – just define a “solver” file

```
net: “lenet_train.prototxt”
base_lr: 0.01
momentum: 0.9
max_iter: 10000
snapshot_prefix: “lenet_snapshot”
solver_mode: GPU
```

All you need to run things on the GPU

```
> caffe train –solver lenet_solver.prototxt –gpu 0
```

Multiple optimization algorithms available: SGD (+momentum), ADAGRAD, NAG

Caffe features

Monitoring the training process

Output to stdout:

```
I0814 14:44:33.410693 2026435328 solver.cpp:294] Iteration 0, Testing net (#0)
I0814 14:44:35.697690 2026435328 solver.cpp:343]     Test net output #0: accuracy = 0.0931
I0814 14:44:35.697720 2026435328 solver.cpp:343]     Test net output #1: loss = 2.30247 (* 1 = 2.30247 loss)
I0814 14:44:35.718361 2026435328 solver.cpp:214] Iteration 0, loss = 2.30184
I0814 14:44:35.718392 2026435328 solver.cpp:229]     Train net output #0: loss = 2.30184 (* 1 = 2.30184 loss)
I0814 14:44:35.718400 2026435328 solver.cpp:486] Iteration 0, lr = 0.001
I0814 14:44:41.550972 2026435328 solver.cpp:214] Iteration 100, loss = 1.72121
I0814 14:44:41.550999 2026435328 solver.cpp:229]     Train net output #0: loss = 1.72121 (* 1 = 1.72121 loss)
I0814 14:44:41.551007 2026435328 solver.cpp:486] Iteration 100, lr = 0.001
I0814 14:44:47.383386 2026435328 solver.cpp:214] Iteration 200, loss = 1.73216
I0814 14:44:47.383415 2026435328 solver.cpp:229]     Train net output #0: loss = 1.73216 (* 1 = 1.73216 loss)
I0814 14:44:47.383424 2026435328 solver.cpp:486] Iteration 200, lr = 0.001
I0814 14:44:53.220012 2026435328 solver.cpp:214] Iteration 300, loss = 1.30751
I0814 14:44:53.220772 2026435328 solver.cpp:229]     Train net output #0: loss = 1.30751 (* 1 = 1.30751 loss)
I0814 14:44:53.220782 2026435328 solver.cpp:486] Iteration 300, lr = 0.001
I0814 14:44:59.053917 2026435328 solver.cpp:214] Iteration 400, loss = 1.16627
I0814 14:44:59.053948 2026435328 solver.cpp:229]     Train net output #0: loss = 1.16627 (* 1 = 1.16627 loss)
I0814 14:44:59.053956 2026435328 solver.cpp:486] Iteration 400, lr = 0.001
I0814 14:45:04.833677 2026435328 solver.cpp:294] Iteration 500, Testing net (#0)
I0814 14:45:06.778378 2026435328 solver.cpp:343]     Test net output #0: accuracy = 0.5589
I0814 14:45:06.778411 2026435328 solver.cpp:343]     Test net output #1: loss = 1.2699 (* 1 = 1.2699 loss)
```

To visualize – pipe, parse and plot or use DIGITS

Caffe features

Deep Neural Network deployment

Standard, compact model format

`caffe train` produces a binary `.caffemodel` file

Easily integrate trained models into data pipelines

Deploy against new data using command line, Python or MATLAB interfaces

Deploy models across HW and OS environments

`.caffemodel` files transfer to any other Caffe installation (including DIGITS)

Caffe features

Deep Neural Network sharing

Caffe Model Zoo hosts community shared models

Benefit from networks that you could not practically train yourself

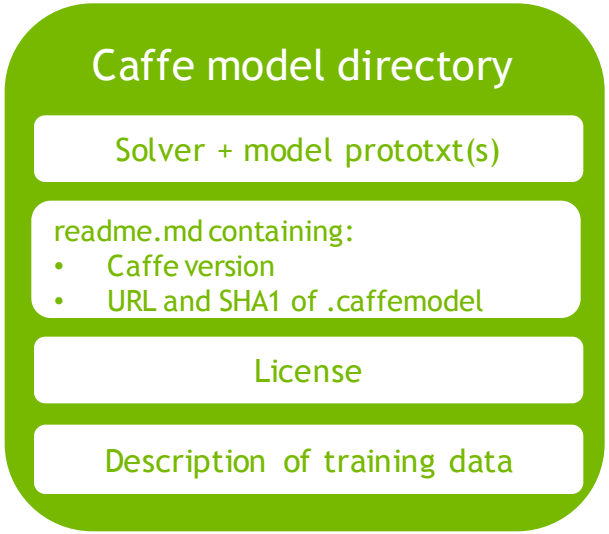
https://github.com/BVLC/caffe/wiki/Model-Zoo

Caffe comes with unrestricted use of BVLC models:

AlexNet

R-CNN

GoogLeNet



Caffe features

Extensible code

```python
import caffe
import numpy as np

class EuclideanLoss(caffe.Layer):

    def setup(self, bottom, top):
        # check input pair
        if len(bottom) != 2:
            raise Exception("Need two inputs to compute distance.")

    def reshape(self, bottom, top):
        # check input dimensions match
        if bottom[0].count != bottom[1].count:
            raise Exception("Inputs must have the same dimension.")
        # difference is shape of inputs
        self.diff = np.zeros_like(bottom[0].data, dtype=np.float32)
        # loss output is scalar
        top[0].reshape(1)

    def forward(self, bottom, top):
        self.diff[...] = bottom[0].data - bottom[1].data
        top[0].data[...] = np.sum(self.diff**2) / bottom[0].num / 2.

    def backward(self, top, propagate_down, bottom):
        for i in range(2):
            if not propagate_down[i]:
                continue
            if i == 0:
                sign = 1
            else:
                sign = -1
            bottom[i].diff[...] = sign * self.diff / bottom[i].num
```

Layer Protocol == Class Interface

Define a class in C++ or Python to extend `Layer`

Include your new layer in a network prototxt

```
layer {
  type: "Python"
  python_param {
    module: "layers"
    layer: "EuclideanLoss"
  }
}
```

Caffe example applications

Example applications

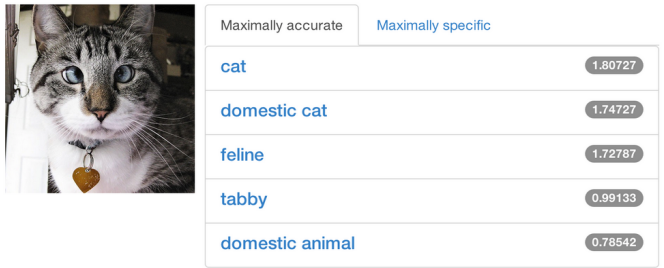
Use case 1: classification of images

Object

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

Open source demo code:

`$CAFFE_ROOT/examples/web_demo`



Scene

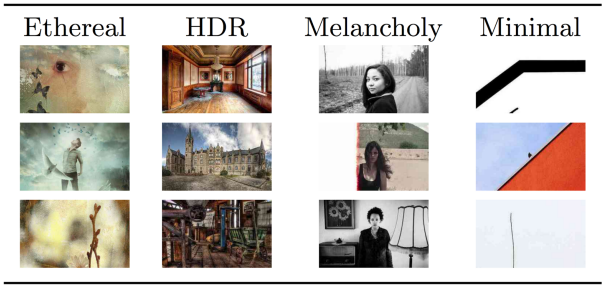
http://places.csail.mit.edu/

B. Zhou et al. NIPS 14

Style

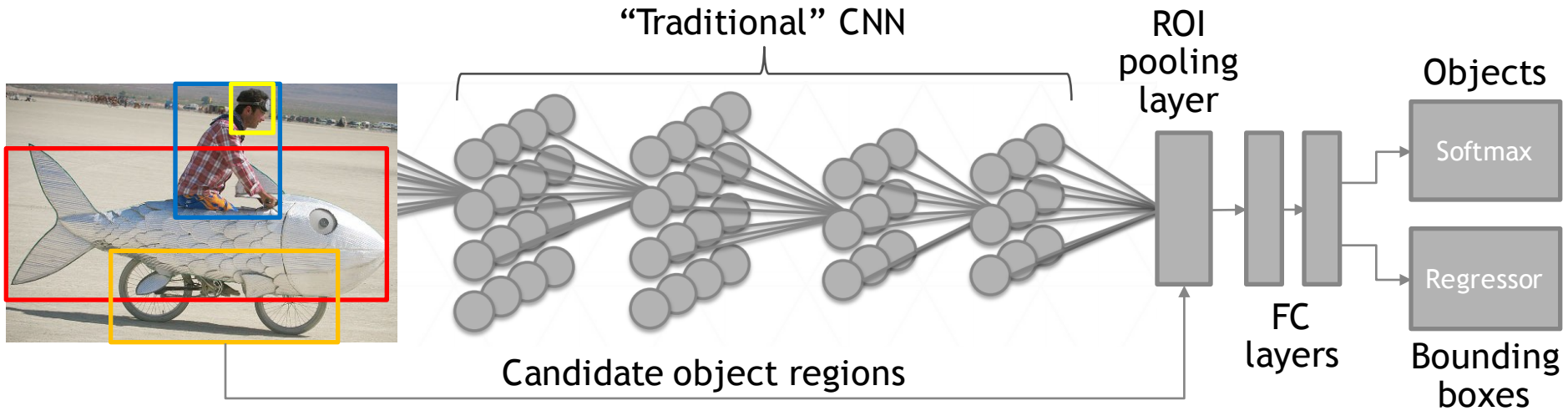
http://demo.vislab.berkeleyvision.org/

Karayev et al. *Recognizing Image Style*. BMVC14



Example applications

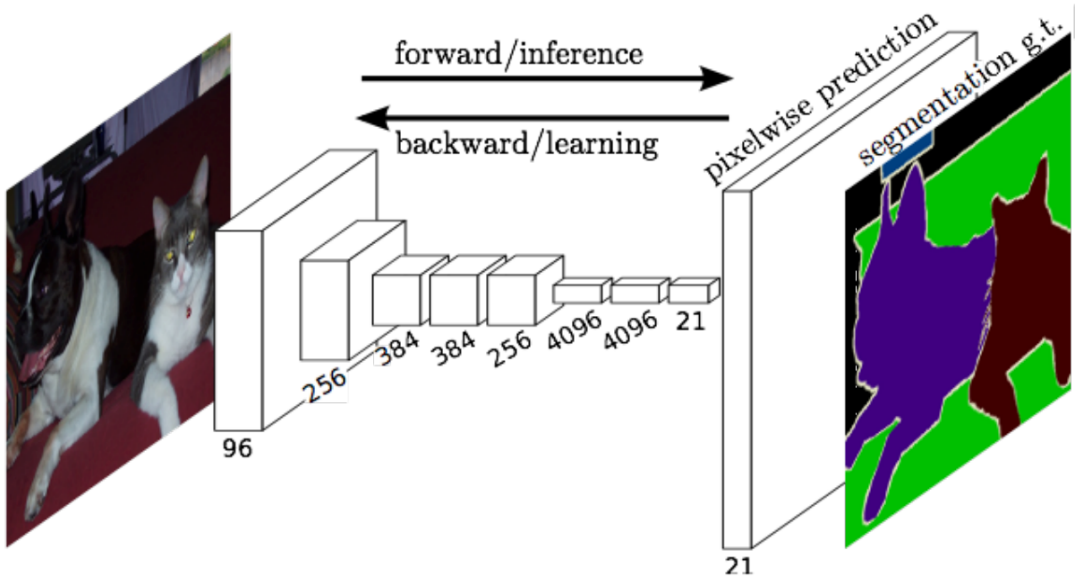
Use case 2: localization



(Fast) Region based Convolutional Networks (R-CNN)
Ross Girshick, Microsoft Research
https://github.com/rbgirshick/fast-rcnn

Example applications

Use case 3: pixel level classification and segmentation



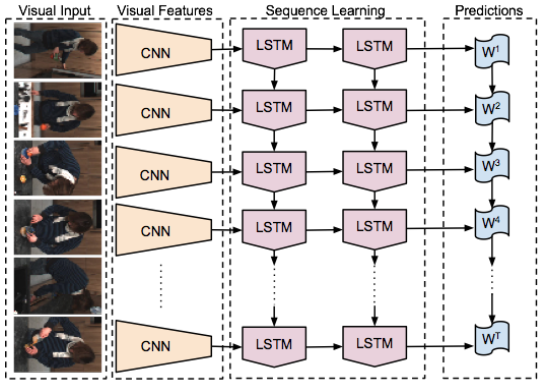
http://fcn.berkeleyvision.org

Long, Shelhamer, Darrell, *Fully convolutional networks for semantic segmentation*, CVPR 2015

Example applications

Use case 4: Sequence learning

- Recurrent Neural Networks (RNNs) and Long Short Term Memory (LSTM)
  - Video
  - Language
  - Dynamic data
- Current Caffe pull request to add support
  - https://github.com/BVLC/caffe/pull/1873
  - http://arxiv.org/abs/1411.4389



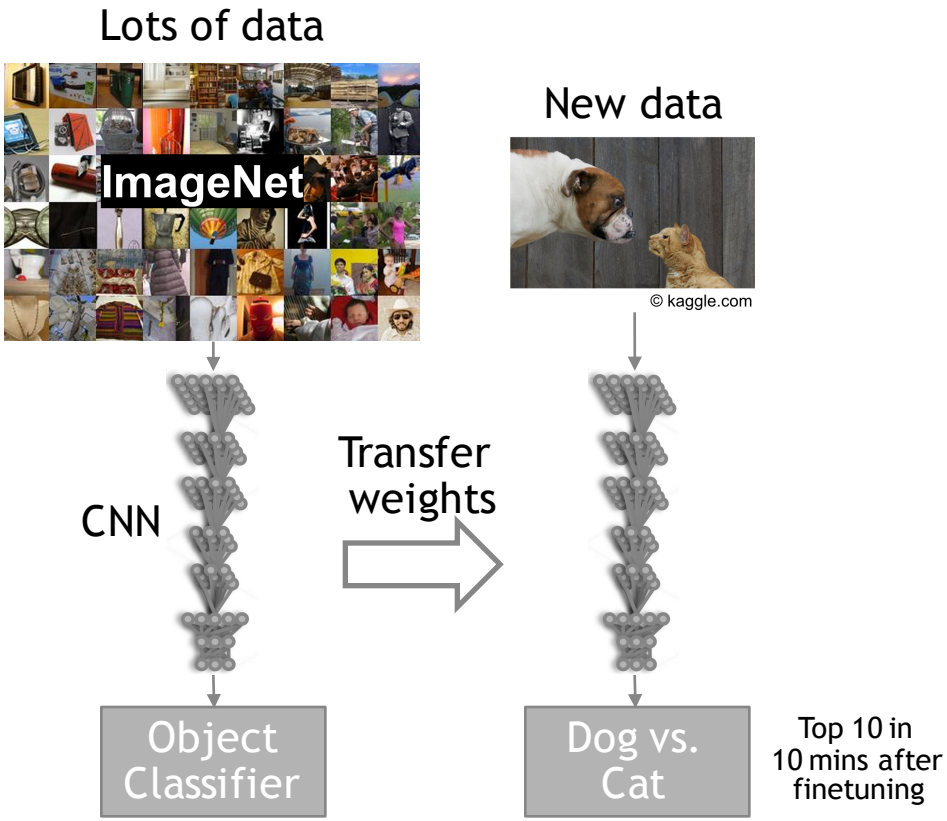
A group of young men playing a game of soccer.

Jeff Donahue et al.

NVIDIA.

Example applications

Use case 5: Transfer learning



- Just change a few lines in the model prototxt file

```
layer {
  name: "data"
  type: "Data"
  data_param {
    source: "ilsvrc12_train"
    …
  }
  …
}
…
layer {
  name: "fc8"
  type: "InnerProduct"
  inner_product_param {
    num_output: 1000
    …
  }
}
```

```
layer {
  name: "data"
  type: "Data"
  data_param: {
    source: "dogcat_train"
    …
  }
  …
}
…
layer {
  name: "fc8-dogcat"
  type: "InnerProduct"
  inner_product_param {
    num_output: 2
    …
  }
}
```

Caffe setup and performance

Caffe setup

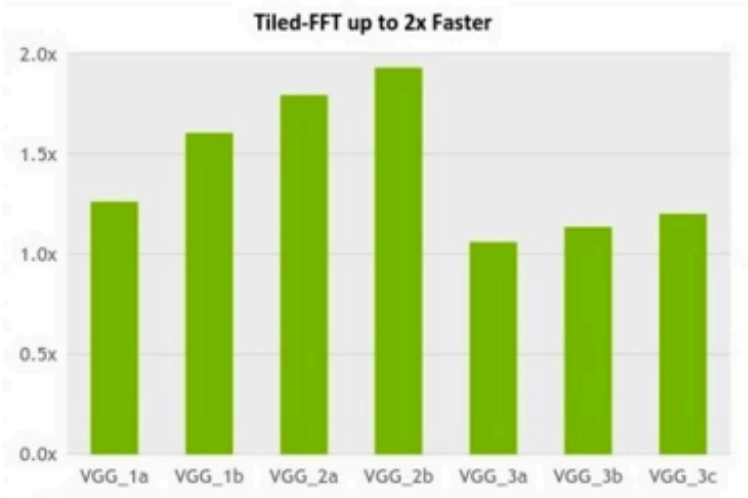
NVIDIA fork enables multiGPU: https://github.com/NVIDIA/caffe

- Tried and tested by BVLC on Ubuntu 14.04/12.04 and OS X 10.8+
- Also demonstrated to compile on RHEL, Fedora and CentOS
- Download source from https://github.com/BVLC/caffe
- Unofficial 64-bit Windows port https://github.com/niuzhiheng/caffe
- Linux setup (see http://caffe.berkeleyvision.org/installation.html)
  - Download
  - Install pre-requisites
  - Install CUDA and cuDNN for GPU acceleration
  - Compile using make

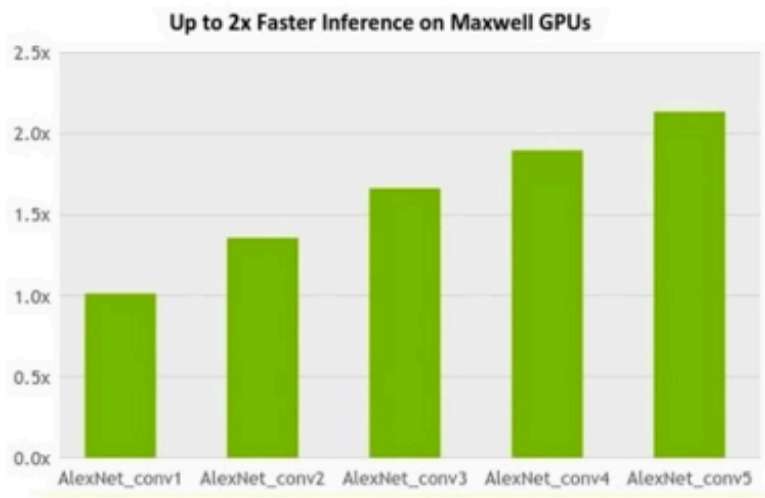
GPU acceleration

`-gpu N` flag tells `caffe` which gpu to use

Alternatively, specify `solver_mode: GPU` in `solver.prototxt`



cuDNN 4 Speedup vs. Non-Tiled FFT
VGG + Caffe, Fwd Pass Convolutional Layers
GeForce TITAN X, Core i7-4930 on Ubuntu 14.04 LTS



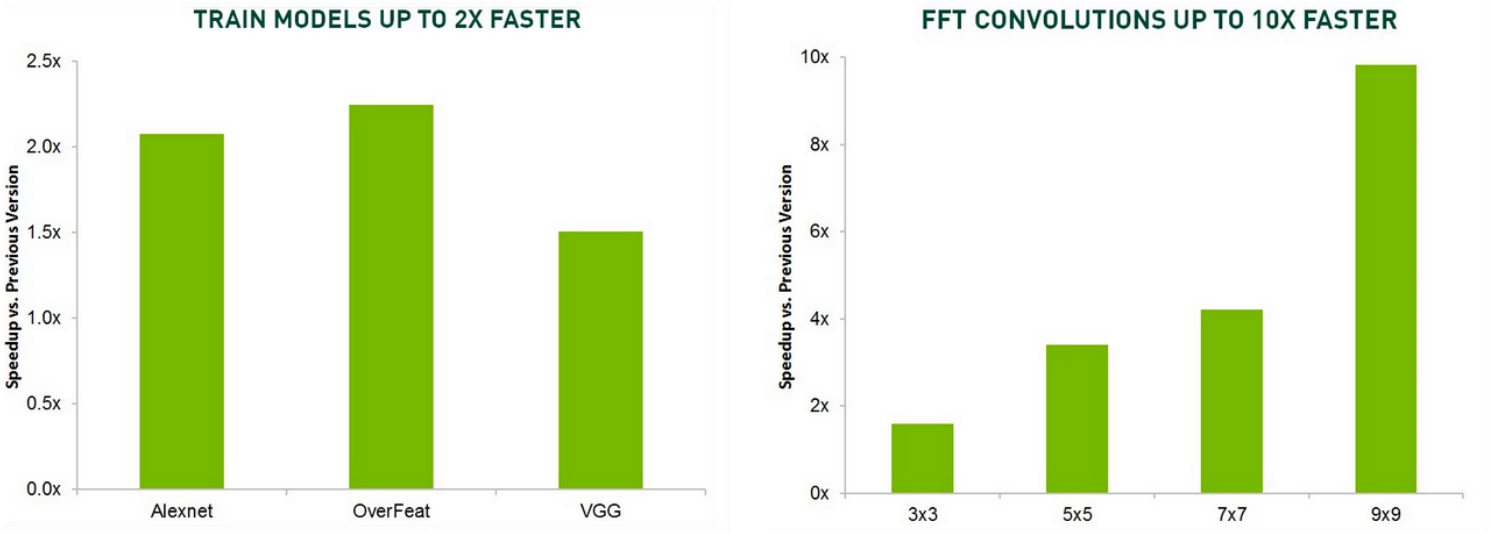
cuDNN 4 Speedup vs. CPU-only for batch = 1
AlexNet + Caffe, Fwd Pass Convolutional Layers
GeForce TITAN X, Core i7-4930 on Ubuntu 14.04 LTS

cuDNN integration

http://developer.nvidia.com/cudnn

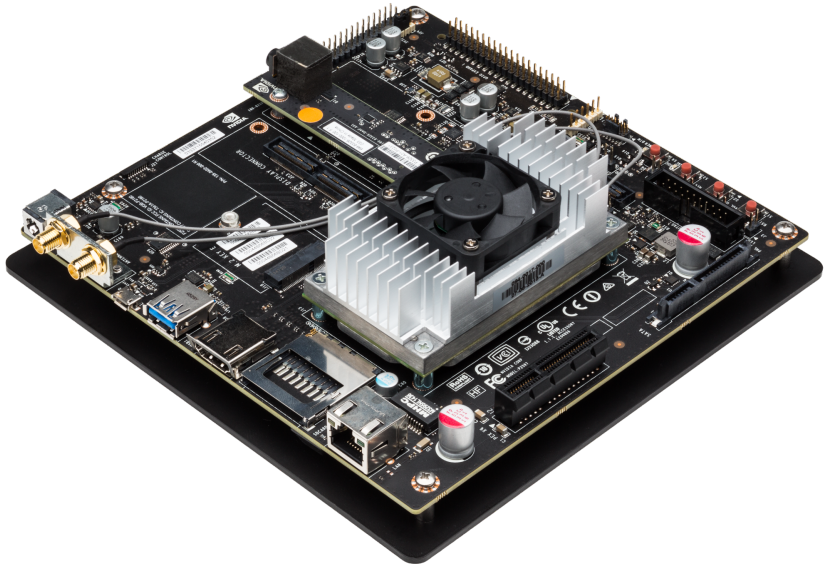
Drop-in support

Install cuDNN, uncomment `USE_CUDNN :=1` in `Makefile.config` before build



cuDNN 3 vs cuDNN 2 on Caffe, Ubuntu 14.04 LTS, Intel(R) Core(TM) i7-4930K CPU @ 3.40GHz, 24GB RAM, GeForce Titan X

Caffe model mobile deployment

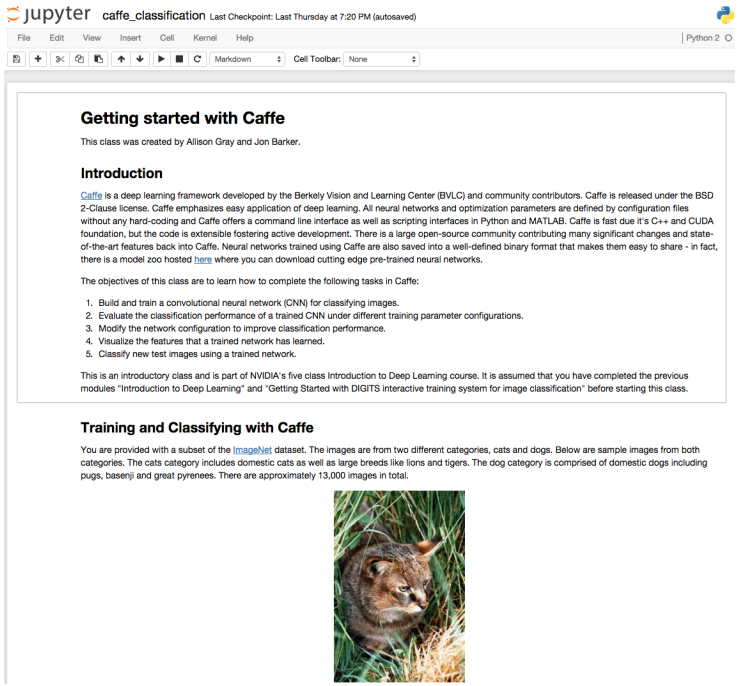


- Jetson TX1
  - NVIDIA Maxwell™ GPU with 256 NVIDIA® CUDA® Cores
  - 4 GB LPDDR4 Memory, 16 GB eMMC 5.1 Flash Storage
  - Connects to 802.11ac Wi-Fi and Bluetooth enabled devices10/100/1000BASE-T
  - No need to change code
- Simply compile Caffe and copy a trained `.caffemodel` to TK1

*Source: http://petewarden.com/2014/10/25/how-to-run-the-caffe-deep-learning-vision-library-on-nvidias-jetson-mobile-gpu-board/

Hands-on lab preview

bit.ly/dlnvlab3



- Use data pre-processing tools
- Edit a network definition
- Train a model
- Improve classification accuracy by modifying network parameters
- Visualize trained network weights
- Deploy a model using Python

Deep Learning Lab Series Schedule

developer.nvidia.com/deep-learning-courses

- Review the other seminars in series

Seminar #2 – Introduction to DIGITs

Seminar #4 - Getting Started with the Theano Framework

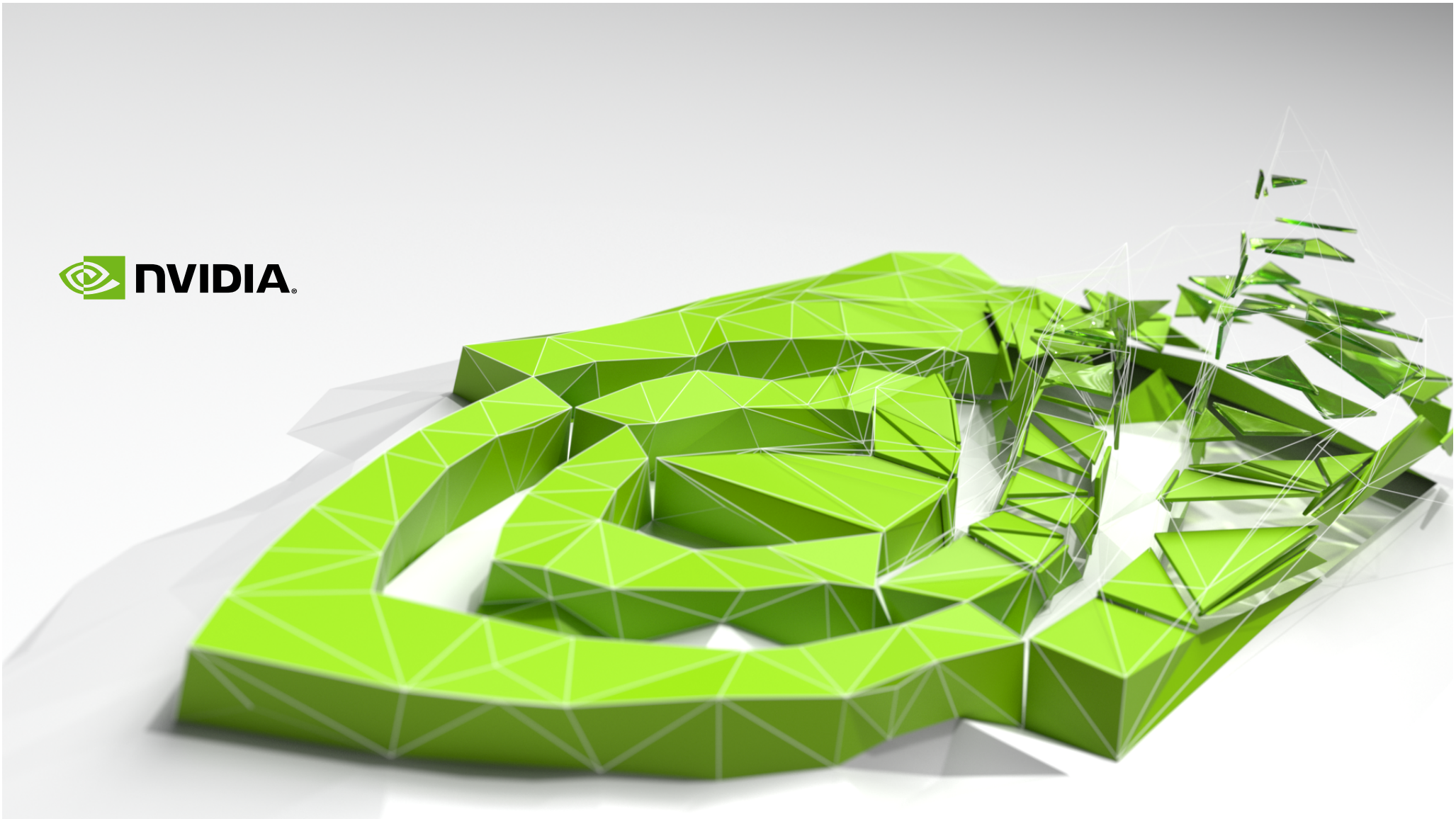
Seminar #5 - Getting Started with the Torch Framework

Hands-on Lab

1. Create an account at nvidia.qwiklab.com
2. Go to “Getting started with Caffe” lab at bit.ly/dlnvlab3
3. Start the lab and enjoy!

Only requires a supported browser, no NVIDIA GPU necessary!

Lab is free until end of Deep Learning Lab series


NVIDIA