

CaffeOnSpark: Deep Learning on Spark Cluster

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SPARK SUMMIT 2016
DATA SCIENCE AND ENGINEERING AT SCALE
JUNE 6-8, 2016 SAN FRANCISCO

Agenda

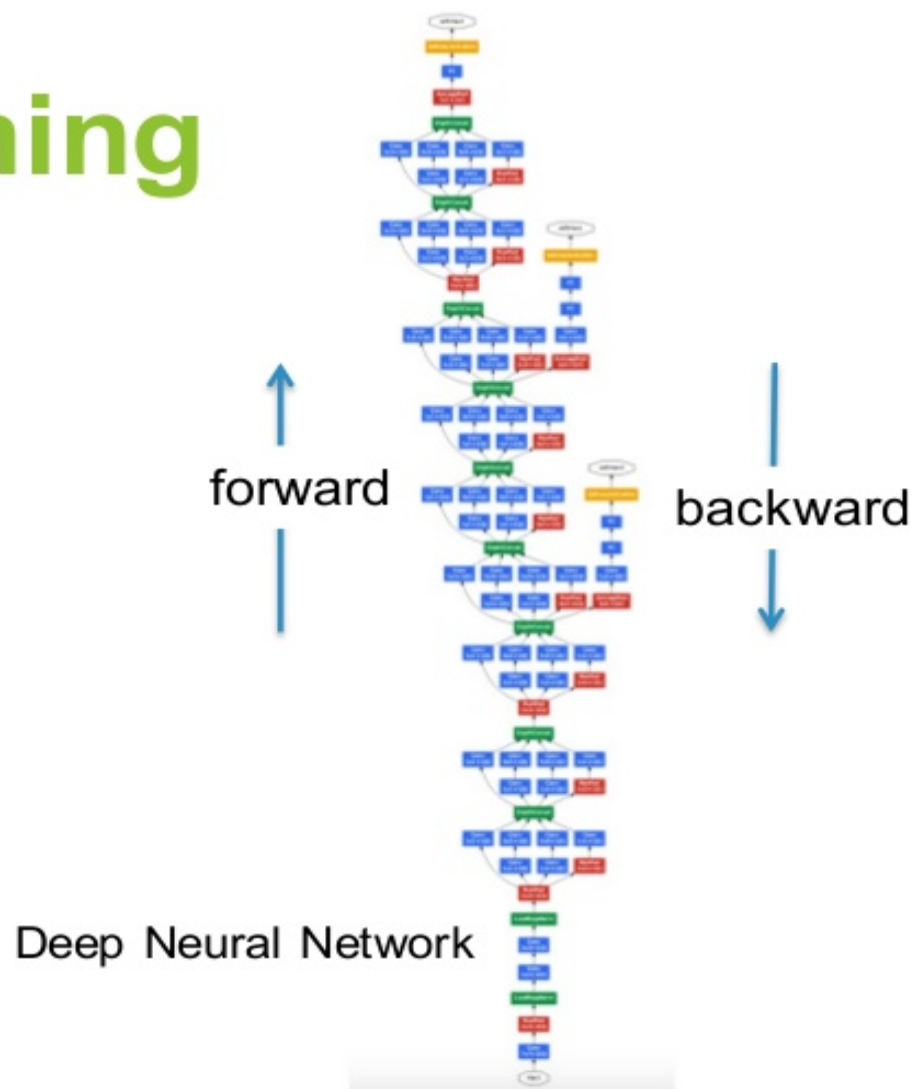
- Why Deep Learning on Spark?
- CaffeOnSpark
 - Architecture
 - API: Scala + Python
- Demo
 - CaffeOnSpark on Python Notebook



Deep Learning

3 6 8 1 7 9 6 6 9 1
6 7 5 7 8 6 3 4 8 5
2 1 7 9 7 1 2 8 4 5
4 8 1 9 0 1 8 8 9 4
7 6 1 8 6 4 1 5 6 0
7 5 9 2 6 5 8 1 9 7
1 2 2 2 2 3 4 4 8 0
0 2 3 8 0 7 3 8 5 7
0 1 4 6 4 6 0 2 4 3
7 1 2 8 7 6 9 8 6 1

Handwritten digits (MNIST)



flickr

You

Explore

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Groups

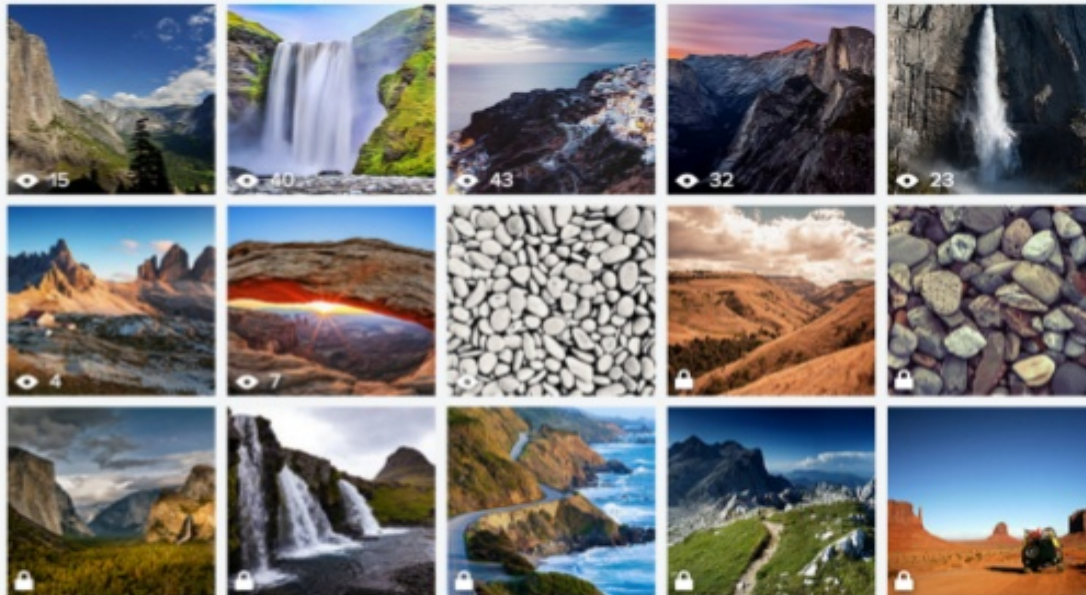
Creations

☒ Show info

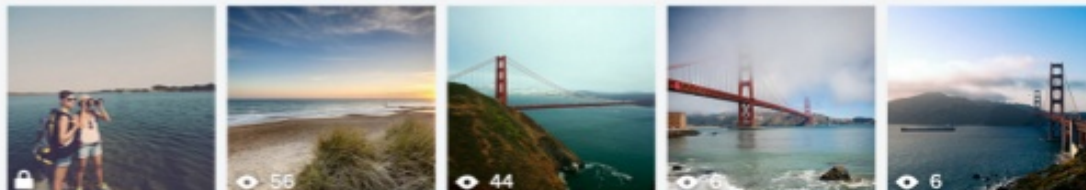
Date taken ▾

Magic View

landscape: rock 23 [Select all](#)



landscape: shore 25 [Select all](#)



Flickr Magic View:

<https://flickr.com/cameraroll>

- Photos organized according to 70 categories
- Empowered by deep learning & machine learning

Flickr DL/ML Pipeline

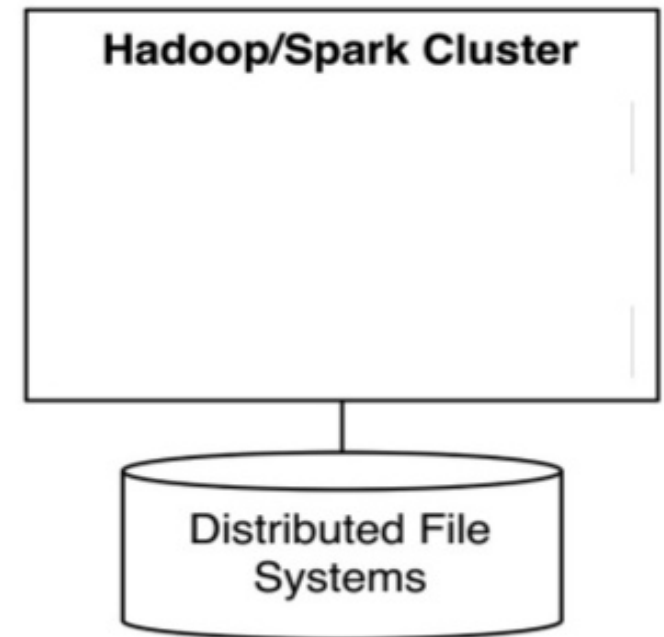
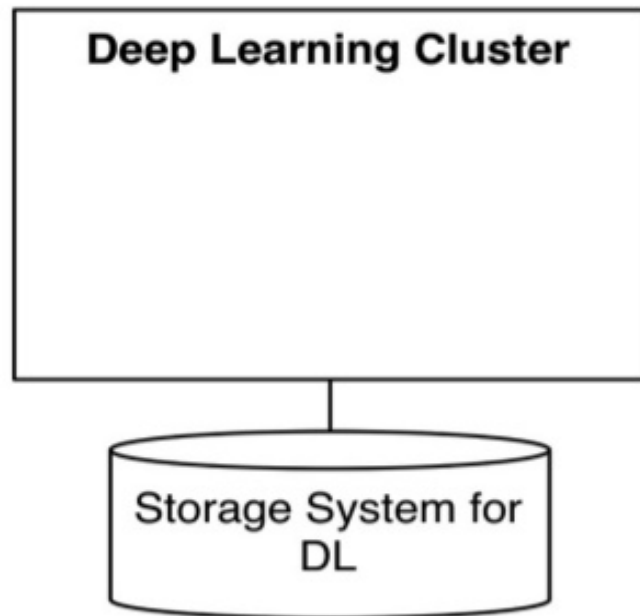


* <http://bit.ly/1KIDfof> by Pierre Garrigues, Deep Learning Summit 2015



SPARK SUMMIT 2016

Deep Learning vs. Spark

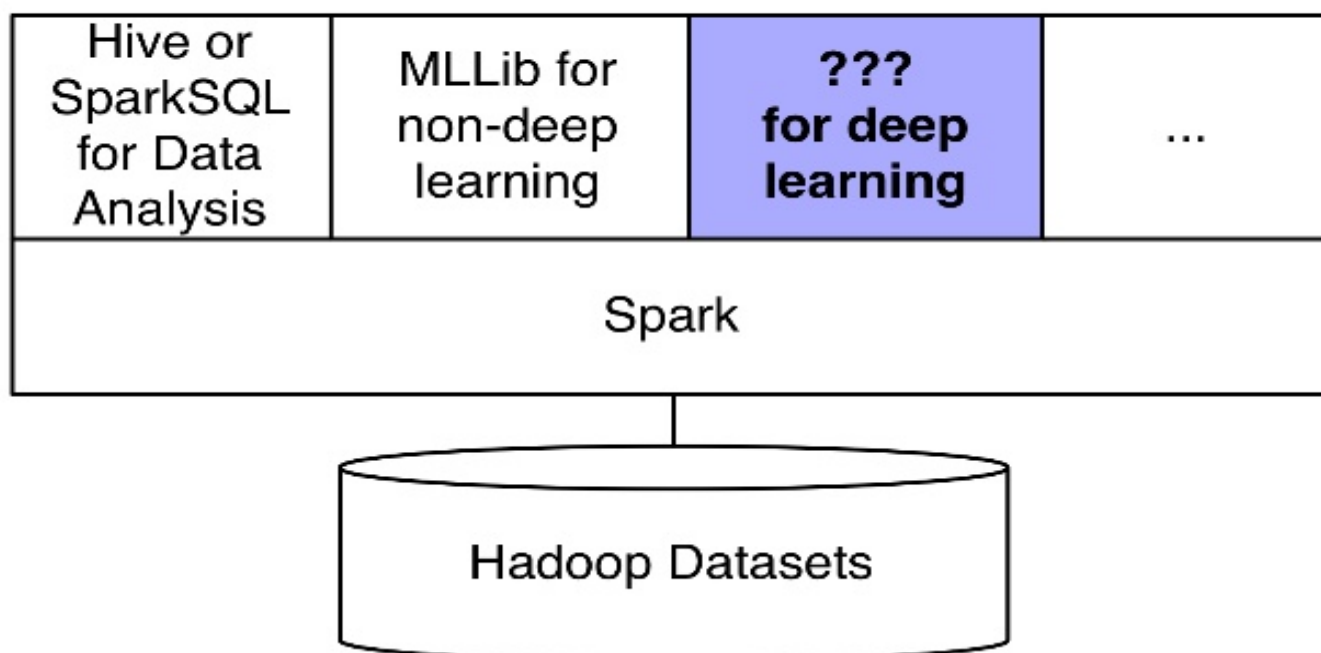


Deep Learning Frameworks

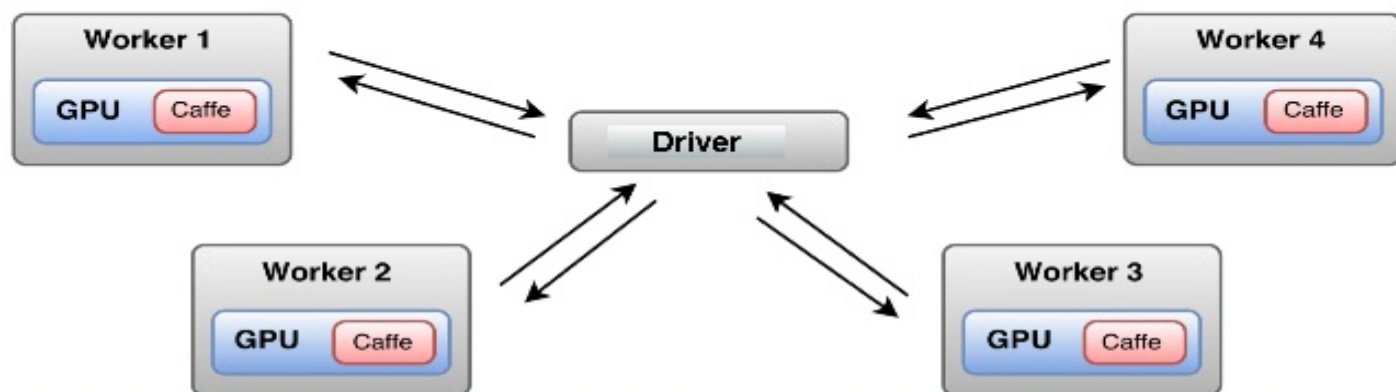
- Theano
- Torch
- Caffe
 - Popular choice for vision community
 - Widely used in Yahoo
- TensorFlow
- ...



Deep Learning on Spark



Related Work: SparkNet & DL4J



REPEAT

- 1) [driver] sc.broadcast(model) to executors
- 2) [executor] apply DL training against a mini-batch of dataset to update models locally
- 3) [driver] aggregate(models) to produce a new model



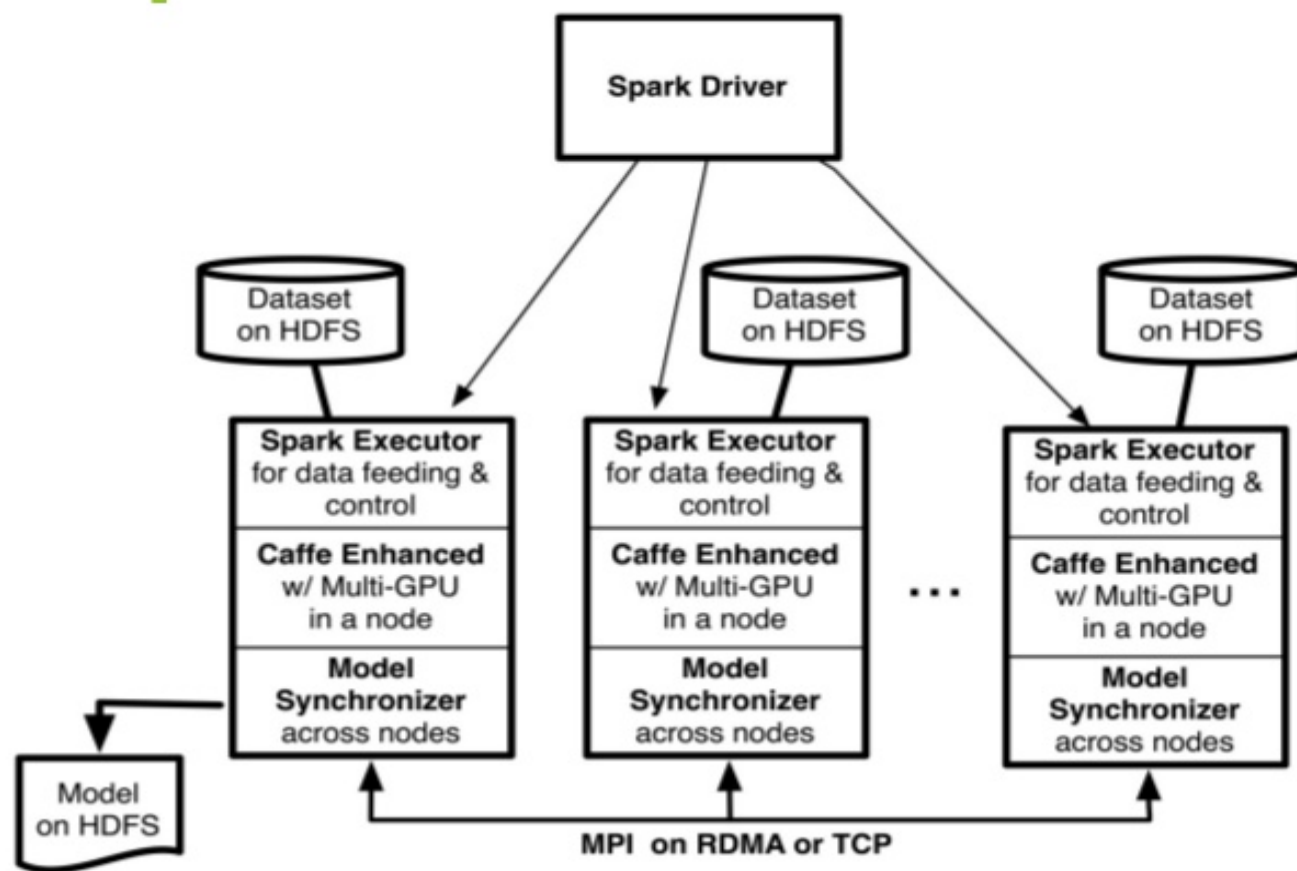
CaffeOnSpark Open Sourced



github.com/yahoo/CaffeOnSpark

- Apache 2.0 license
- Distributed deep learning
 - GPU or CPU
 - Ethernet or InfiniBand
- Easily deployed on public cloud or private cloud

CaffeOnSpark: Scalable Architecture

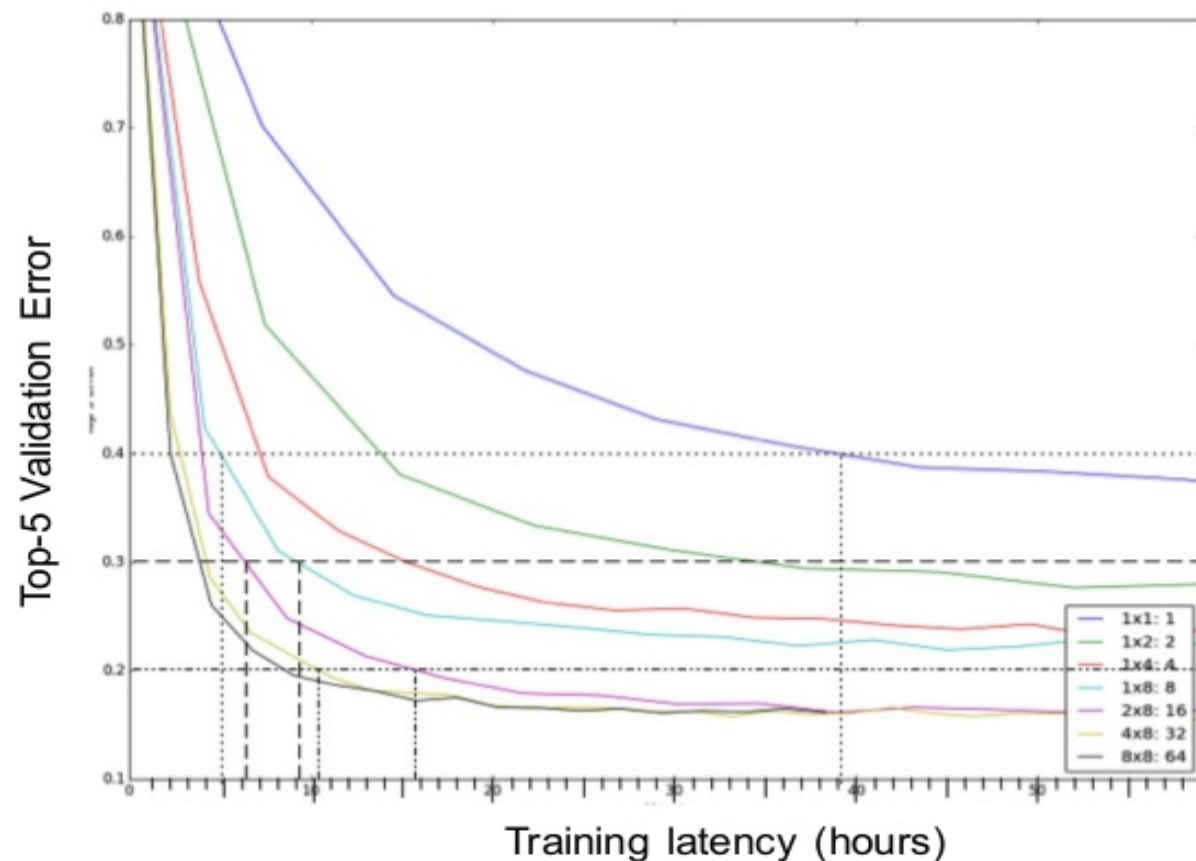


CaffeOnSpark: Deployment Options

- Single node
 - Spark-submit –master local
- Multiple nodes w/ ethernet connection
 - Spark-submit –master URL –connection ethernet
 - Ex. EC2
- Multiple nodes w/ Infiniband connection
 - Spark-submit –master URL –connection infiniband
 - Ex., Yahoo Hadoop cluster



Deep Learning: 19x Speedup (est.)



CaffeOnSpark: DL Made Easy

Spark CLI

- spark-submit
--num-executors *#_Processes*
--class com.yahoo.ml.CaffeOnSpark
caffe-on-spark.jar
-devices *#_gpus_per_proc*
-conf *solver_config_file*
-model *model_file*
-train | -test | -feature

Caffe Configuration

```
layer {  
  name: "data"  
  type: "MemoryData"  
  source_class="com.yahoo.ml.caffe.LMDB"  
  memory_data_param {  
    source: "hdfs:///mnist/trainingdata/"  
    batch_size: 64;  
    channels: 1;  
    height: 28;  
    width: 28;  
  }  
  ...  
}
```


CaffeOnSpark: One Program (Scala)

<http://bit.ly/21ZY1c2>

```
cos = new CaffeOnSpark(ctx) conf = new Config(ctx, args).init()
```

```
// (1) training DL model
```

```
dl_train_source = DataSource.getSource(conf, true) cos.train(dl_train_source)
```

```
// (2) extract features via DL
```

```
lr_raw_source = DataSource.getSource(conf, false) ext_df = cos.features(lr_raw_s
```

```
// (3) apply ML
```

```
lr_input=ext_df.withColumn("L", cos.floats2doubleUDF(ext_df(conf.label)))
```

```
.withColumn("F", cos.floats2doublesUDF(ext_df(conf.features(0)))) lr = new
```

```
LogisticRegression().setLabelCol("L").setFeaturesCol("F") lr_model = lr.fit(lr_input
```

Deep Learning

Non-deep
Learning



CaffeOnSpark: One Notebook (Python)

<http://bit.ly/1REZ0cN>

Feature Extraction

```
In [50]: args['features']='accuracy,ip1,ip2'  
args['label']='label'  
cfg=Config(sc,args)
```

```
In [52]: dl_feature_source = DataSource(sc).getSource(cfg,False)
```

```
In [54]: f=cos.features(dl_feature_source)
```

```
In [55]: f.show(5)
```

SampleID	accuracy	ip1	ip2	label
00000000	[1.0]	[-0.0, 3.109636, ...]	[-0.6478175, -1.4...	[7.0]
00000001	[1.0]	[1.3683326, -0.0, ...]	[2.0906663, 1.048...	[2.0]
00000002	[1.0]	[1.5641443, -0.0, ...]	[-0.773368, 10.61...	[1.0]
00000003	[1.0]	[-0.0, 1.9505613, ...]	[16.46351, -6.917...	[0.0]
00000004	[1.0]	[0.5979191, 0.075...	[-0.48371825, -2....]	[4.0]

```
In [45]: dl_train_source = DataSource(sc).getSource(cfg,True)
```

```
In [46]: cos.train(dl_train_source)
```

CaffeOnSpark: UI & Logs

Spark UI

Jobs Stages Storage Environment Executors

com.yahoo.rdd.CaffeOnSpark application UI

Spark Jobs (1)

Total Uptime: 32 h
Scheduling Mode: FIFO
Active Jobs: 1
Completed Jobs: 47
+ Drill Timeline

Active Jobs (1)

Job ID	Description	Submitted	Duration	Stages: Succeeded/Total	Tasks (for all stages): Succeeded/Total
47	reduce at CaffeOnSpark job0200	2016/01/26 05:40:00	31 min	0/2	89/192

Completed Jobs (47)

Job ID	Description	Submitted	Duration	Stages: Succeeded/Total	Tasks (for all stages): Succeeded/Total
46	reduce at CaffeOnSpark job0200	2016/01/26 05:44:51	41 min	1/1 [1 skipped]	90/515 [947 skipped]
45	reduce at CaffeOnSpark job0200	2016/01/26 05:40:40	42 min	1/1 [1 skipped]	90/515 [947 skipped]
44	reduce at CaffeOnSpark job0200	2016/01/26 05:36:31	42 min	1/1 [1 skipped]	90/515 [947 skipped]
43	reduce at CaffeOnSpark job0200	2016/01/26 05:31:40	47 min	1/1 [1 skipped]	90/515 [947 skipped]
42	reduce at CaffeOnSpark job0200	2016/01/26 05:27:35	43 min	1/1 [1 skipped]	90/515 [947 skipped]
41	reduce at CaffeOnSpark job0200	2016/01/26 05:23:24	41 min	1/1 [1 skipped]	90/515 [947 skipped]
40	reduce at CaffeOnSpark job0200	2016/01/26 05:19:15	41 min	1/1 [1 skipped]	90/515 [947 skipped]
39	reduce at CaffeOnSpark job0200	2016/01/26 05:15:05	41 min	1/1 [1 skipped]	90/515 [947 skipped]
38	reduce at CaffeOnSpark job0200	2016/01/26 05:10:40	43 min	1/1 [1 skipped]	90/515 [947 skipped]
37	reduce at CaffeOnSpark job0200	2016/01/26 05:06:30	42 min	1/1 [1 skipped]	90/515 [947 skipped]
36	reduce at CaffeOnSpark job0200	2016/01/26 05:02:27	42 min	1/1 [1 skipped]	90/515 [947 skipped]
35	reduce at CaffeOnSpark job0200	2016/01/26 04:58:17	42 min	1/1 [1 skipped]	90/515 [947 skipped]
34	reduce at CaffeOnSpark job0200	2016/01/26 04:54:07	42 min	1/1 [1 skipped]	90/515 [947 skipped]
33	reduce at CaffeOnSpark job0200	2016/01/26 04:49:50	43 min	1/1 [1 skipped]	90/515 [947 skipped]
32	reduce at CaffeOnSpark job0200	2016/01/26 04:45:40	42 min	1/1 [1 skipped]	90/515 [947 skipped]
31	reduce at CaffeOnSpark job0200	2016/01/26 04:41:32	43 min	1/1 [1 skipped]	90/515 [947 skipped]
30	reduce at CaffeOnSpark job0200	2016/01/26 04:37:12	42 min	1/1 [1 skipped]	90/515 [947 skipped]
29	reduce at CaffeOnSpark job0200	2016/01/26 04:33:02	42 min	1/1 [1 skipped]	90/515 [947 skipped]
28	reduce at CaffeOnSpark job0200	2016/01/26 04:28:40	43 min	1/1 [1 skipped]	90/515 [947 skipped]
27	reduce at CaffeOnSpark job0200	2016/01/26 04:24:29	42 min	1/1 [1 skipped]	90/515 [947 skipped]
26	reduce at CaffeOnSpark job0200	2016/01/26 04:20:19	42 min	1/1 [1 skipped]	90/515 [947 skipped]
25	reduce at CaffeOnSpark job0200	2016/01/26 04:16:10	42 min	1/1 [1 skipped]	90/515 [947 skipped]
24	reduce at CaffeOnSpark job0200	2016/01/26 04:11:55	42 min	1/1 [1 skipped]	90/515 [947 skipped]

Firefox File Edit View History Bookmarks Tools Window Help

Logs for container_... 144364...

gph1181n07 blueygrd.yahoo.com:8042/models/caffe-logs/container_... 1443645084503_1526577...
container_... 1443645084503_1526577_01_000002/caffe-net/caffe-net


```

layer {
  name: "conv1"
  type: "Convolution"
  bottom: "ip1"
  top: "conv1"
  include: {
    phase: "TRAIN"
  }
}

layer {
  name: "loss"
  type: "SoftmaxWithLoss"
  bottom: "conv1"
  top: "loss"
}

11025 21:56:13.067219 23673 layer_factory.hpp:75] Creating Layer data
11025 21:56:13.067260 23673 net.cpp:91] Creating Layer data
11025 21:56:13.067351 23673 net.cpp:458] data -> data
11025 21:56:13.067384 23673 net.cpp:458] conv1 -> conv1
11025 21:56:13.067425 23673 net.cpp:120] Setting up data
11025 21:56:13.068010 23673 net.cpp:129] Top shape: 100 1 28 28 (78400)
11025 21:56:13.068530 23673 net.cpp:129] Top shape: 100 1001
11025 21:56:13.068615 23673 layer_factory.hpp:75] Creating Layer label_data_1_split
11025 21:56:13.069040 23673 net.cpp:91] Creating Layer label_data_1_split
11025 21:56:13.069051 23673 net.cpp:452] label_data_1_split -> label
11025 21:56:13.069104 23673 net.cpp:458] label_data_1_split -> label_data_1_split
11025 21:56:13.069163 23673 net.cpp:458] label_data_1_split -> label_data_1_split
11025 21:56:13.069270 23673 net.cpp:120] Setting up label_data_1_split
11025 21:56:13.069377 23673 net.cpp:129] Top shape: 100 1 1 1 (100)
11025 21:56:13.069462 23673 net.cpp:129] Top shape: 100 1 1 1 (100)
11025 21:56:13.069524 23673 layer_factory.hpp:75] Creating Layer conv1
11025 21:56:13.069550 23673 net.cpp:91] Creating Layer conv1
11025 21:56:13.069582 23673 net.cpp:458] conv1 -> conv1
11025 21:56:13.069610 23673 net.cpp:458] conv1 -> conv1
11025 21:56:13.069643 23673 net.cpp:120] Setting up conv1
11025 21:56:13.069673 23673 net.cpp:129] Top shape: 100 20 24 24 (1152000)
11025 21:56:13.069722 23673 layer_factory.hpp:75] Creating Layer pool1
11025 21:56:13.069750 23673 net.cpp:91] Creating Layer pool1
11025 21:56:13.069781 23673 net.cpp:452] pool1 -> conv1
11025 21:56:13.069810 23673 net.cpp:458] pool1 -> pool1
11025 21:56:13.069842 23673 net.cpp:120] Setting up pool1
11025 21:56:13.069870 23673 net.cpp:129] Top shape: 100 20 12 12 (300000)
11025 21:56:13.069901 23673 layer_factory.hpp:75] Creating Layer conv2
11025 21:56:13.069934 23673 net.cpp:91] Creating Layer conv2
11025 21:56:13.069962 23673 net.cpp:458] conv2 -> pool1
11025 21:56:13.069990 23673 net.cpp:458] conv2 -> conv2
11025 21:56:13.070022 23673 net.cpp:120] Setting up conv2
11025 21:56:13.070054 23673 net.cpp:129] Top shape: 100 50 8 8 (320000)
11025 21:56:13.070086 23673 layer_factory.hpp:75] Creating Layer pool2
11025 21:56:13.070118 23673 net.cpp:91] Creating Layer pool2
11025 21:56:13.070149 23673 net.cpp:452] pool2 -> conv2
11025 21:56:13.070180 23673 net.cpp:458] pool2 -> pool2
11025 21:56:13.070211 23673 net.cpp:120] Setting up pool2
11025 21:56:13.070241 23673 net.cpp:129] Top shape: 100 50 4 4 (80000)
11025 21:56:13.070272 23673 layer_factory.hpp:75] Creating Layer ip1
11025 21:56:13.070303 23673 net.cpp:91] Creating Layer ip1
11025 21:56:13.070334 23673 net.cpp:452] ip1 -> pool2

```



Demo: CaffeOnSpark on EC2

- <https://github.com/yahoo/CaffeOnSpark/wiki>
 - Get started on EC2
 - Python for CaffeOnSpark



Summary

- CaffeOnSpark open sourced
 - <https://github.com/yahoo/CaffeOnSpark>
 - Empower Flickr and other Yahoo services
 - Scalable DL made easy



THANK YOU.

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