Lecture 2:

Caffe: getting started

Forward propagation

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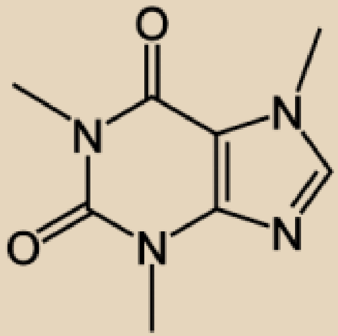
Agenda

- Caffe – getting started
- Test description
- Network topology definition
- Basic layers: definition and forward propagation
  - Convolutional
  - Pooling
  - ReLU
  - Fully Connected layer
  - Softmax
- Implementation details of Convolutional layer
- MNIST training

Open-source Deep Learning libraries

1. http://caffe.berkeleyvision.org/
   Very fast. C++/ CUDA, Python and Matlab wrappers
2. https://code.google.com/p/cuda-convnet2/
   Just released. Excellent tutorial. Best Cuda code.
3. http://torch.ch/
   Excellent tutorial, C++/Cuda, Lua.
4. http://deeplearning.net/software/pylearn2/:
   Integrated with Theano, C++/Cuda, Python
5. http://torontodeeplearning.github.io/convnet/
   C++/CUDA.



Caffe:

Convolutional Architecture for Fast Feature Embedding

Created by Yangqing Jia
Developed by BVLC
caffe.berkeleyvision.org
bvlc.eecs.berkeley.edu

BVLC

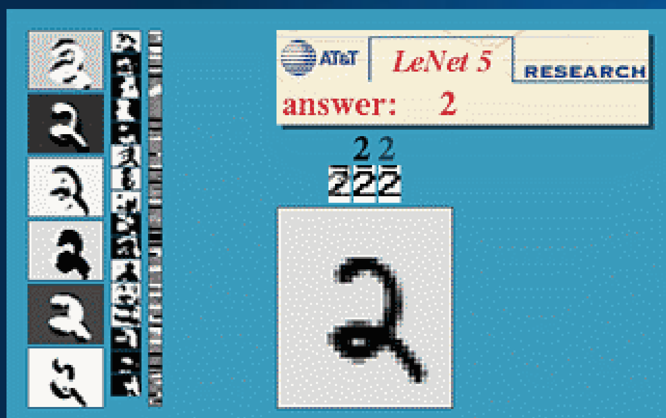
Caffe: installation

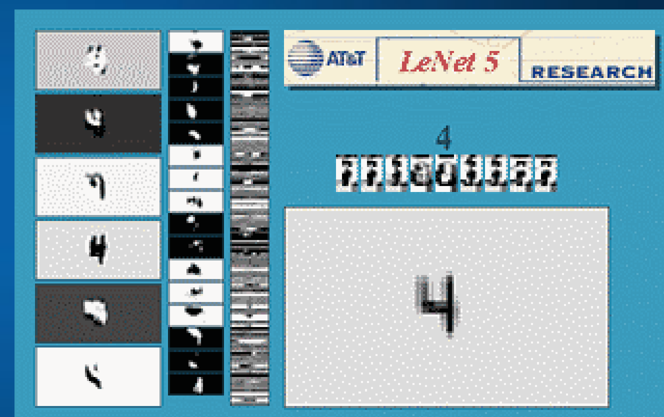
1. Ubuntu 12.04
2. Cuda 5.5 or 6.0
   – SDK - required, NVidia card is optional ☺
3. BLAS:
   – OpenBLAS or Intel MKL(Math Kernel Lib)

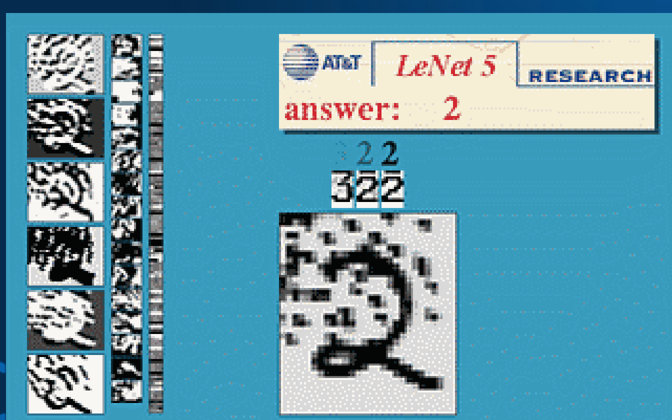
$ git clone https://github.com/BVLC/caffe

Caffe: example 1 - MNIST

- Database: http://yann.lecun.com/exdb/mnist/
- Demo: http://yann.lecun.com/exdb/lenet/index.html







Caffe: database format

src/tools/convert_mnist_data.cpp: MNIST format → leveldb

1. leveldb: https://code.google.com/p/leveldb/
   - <key,value>: arbitrary byte arrays; data is stored sorted by key; callers can provide a custom comparison function to override the sort order.
   - basic operations : Put(key,value), Get(key), Delete(key).
2. caffe "dev" branch supports lmdb: http://symas.com/mdb/
   - <key;value> ; data is stored sorted by key
   - uses memory-mapped files: the read performance of a pure in-memory db while still offering the persistence of standard disk-based db
   - concurrent

Caffe: configuration files

1. Solver descriptor:
   - http://caffe.berkeleyvision.org/mnist_solver_prototxt.html

1. Net descriptor:
   - http://caffe.berkeleyvision.org/mnist_prototxt.html

Parameters are defined in src/caffe/proto/caffe.proto.

Protobuf (Google protocol buffers) format - easy-to-use automatic generation of configuration files: https://developers.google.com/protocol-buffers/docs/overview

LeNet Topology

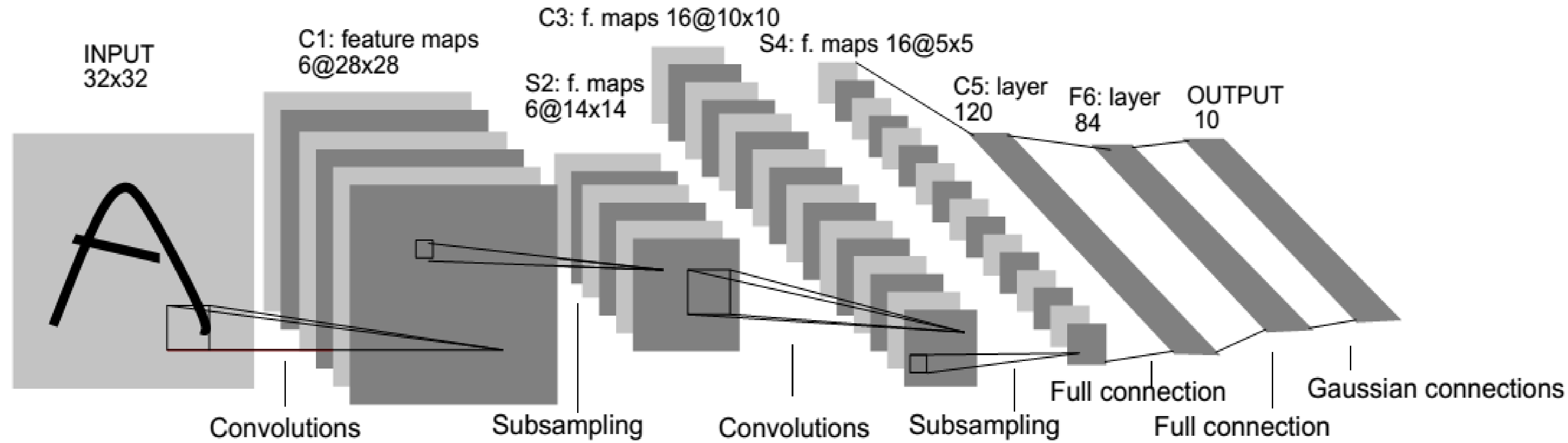


Fig. 2. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical.

http://yann.lecun.com/exdb/publis/pdf/lecun-01a.pdf

LeNet topology

FORWARD

Soft Max

Inner Product

ReLUP

Inner Product

Pooling [2x2, stride 2]

Convolutional layer [5x5]

Pooling [2x2, stride 2]

Convolutional layer [5x5]

Data Layer

BACKWARD

Layer:: Forward( )

```
class Layer {
    Setup (bottom, top);            // initialize layer
    Forward (bottom, top);          //compute next layer
    Backward( top, bottom);         //compute gradient
}
```

Layer::Forward( ) propagate y_{l-1} to next layer:

$$y_l = f(w_l, y_{l-1})$$

Data Layer

mnist-train-leveldb

```
name: "mnist"
  type: DATA
  data_param {
    source: "mnist-train-leveldb"
    batch_size: 64
    scale: 0.00390625
  }
  top: "data"
  top: "label"
```

data

label

Convolutional Layer

Data

```
name: "conv1"
  type: CONVOLUTION
  blobs_lr: 1.
  convolution_param {
    num_output: 20
    kernelsize: 5
    stride: 1
    weight_filler {
      type: "xavier"
    }
    bias_filler {
      type: "constant"
    }
  }
  bottom: "data"
  top: "conv1”
```

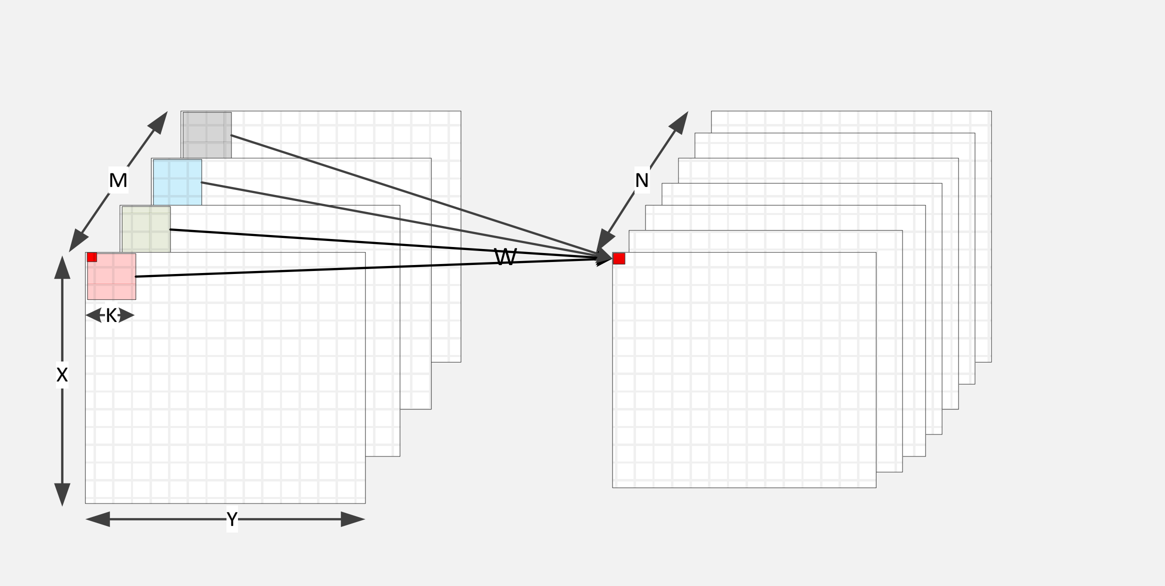
conv1

conv1

conv1

conv1

Convolutional Layer



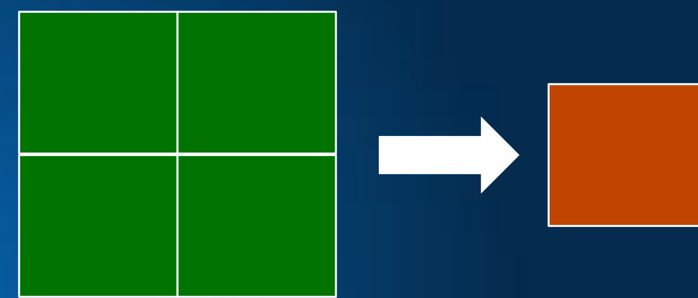

```
for (n = 0;  n < N;  n++)
  for (m = 0;  m < M;  m ++)
    for(y = 0; y<Y; y++)
     for(x = 0; x<X; x++)
        for (p = 0; p< K; p++)
          for (q = 0;  q< K; q++)
```

$y_L(n; x, y) \mathrel{+}= y_{L-1}(m, x+p, y+q) * w(m, n; p, q);$

Add bias…

Pooling Layer

```
name: "pool1"
 type: POOLING
 pooling_param {
   kernel_size: 2
   stride: 2
   pool: MAX
 }
 bottom: "conv1"
 top: "pool1"
```



for (p = 0; p< k; p++)

for (q = 0; q< k; q++)

$$y_L(x, y) = \max\left(y_L(x, y),\ y_{L-1}(x*s + p, y*s + q) \right);$$

Pooling helps to extract features that are increasingly invariant to local transformations of the input image.

Inner product (Fully Connected) Layer

```
name: "ip1"
  type: INNER_PRODUCT
  blobs_lr: 1.
  blobs_lr: 2.
  inner_product_param {
    num_output: 500
    weight_filler {
      type: "xavier"
    }
    bias_filler {
      type: "constant"
    }
  }
  bottom: "pool2"
  top: "ip1"
```

$$Y_L(n) = \sum W_L(n, m) * Y_{L-1}(m)$$

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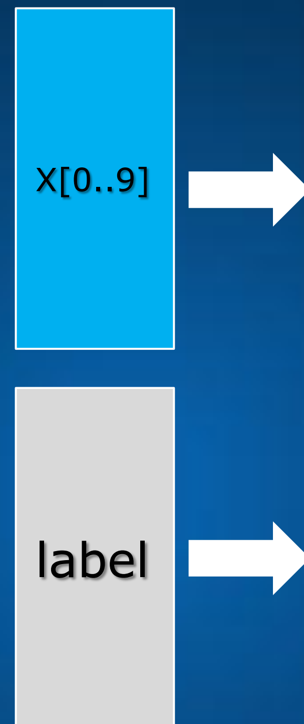
ReLU Layer

```
layers {
  name: "relu1"
  type: RELU
  bottom: "ip1"
  top: "ip1"
}
```

$$Y_L(n; x, y) = \max(Y_{L-1}(n; x, y), 0);$$

SoftMax + Loss Layer




```
layers {
  name: "loss"
  type:
SOFTMAX_LOSS
  bottom: "ip2"
  bottom: "label"
}
```

Combines softmax:

$$Y_L\,[i] = \exp\,(Y_{L-1}[i]\,)\,/\,(\,\Sigma\,(Y_{L-}[i]\,);$$

with log-loss :

$$E = -\log\,(Y_{L-}(\text{label}\,(n)\,)$$

LeNet topology

Soft Max	10x1
Inner Product	10x1
ReLUP	500x1
Inner Product	500x1
Pooling [2x2, stride 2]	50x4x4
Convolutional layer [5x5]	50x8x8
Pooling [2x2, stride 2]	20x12x12
Convolutional layer [5x5]	20x24x24
Data Layer	1x28x28

SOME IMPLEMENTATION DETAILS

Data Layer

All data is stored as *BLOBs – Binary (Basic) Large Objects*

```
class Blob {
        Blob( int num,  int channels,  int height,  int width);
        const Dtype* cpu_data() const;
        const Dtype* gpu_data() const;
        ...
    protected:
        shared_ptr<SyncedMemory> data_;  // containter for cpu_ / gpu_memory
        shared_ptr<SyncedMemory> diff_;    // gradient
        int num_;
        int channels_;
        int height_;
        int width_;
        int count_;
}
```

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Convolutional Layer : im2col

Conv Layer implementation is based on reduction to matrix – matrix multiply (See Chellapilla et all , “High Performance Convolutional Neural Networks for Document Processing”)

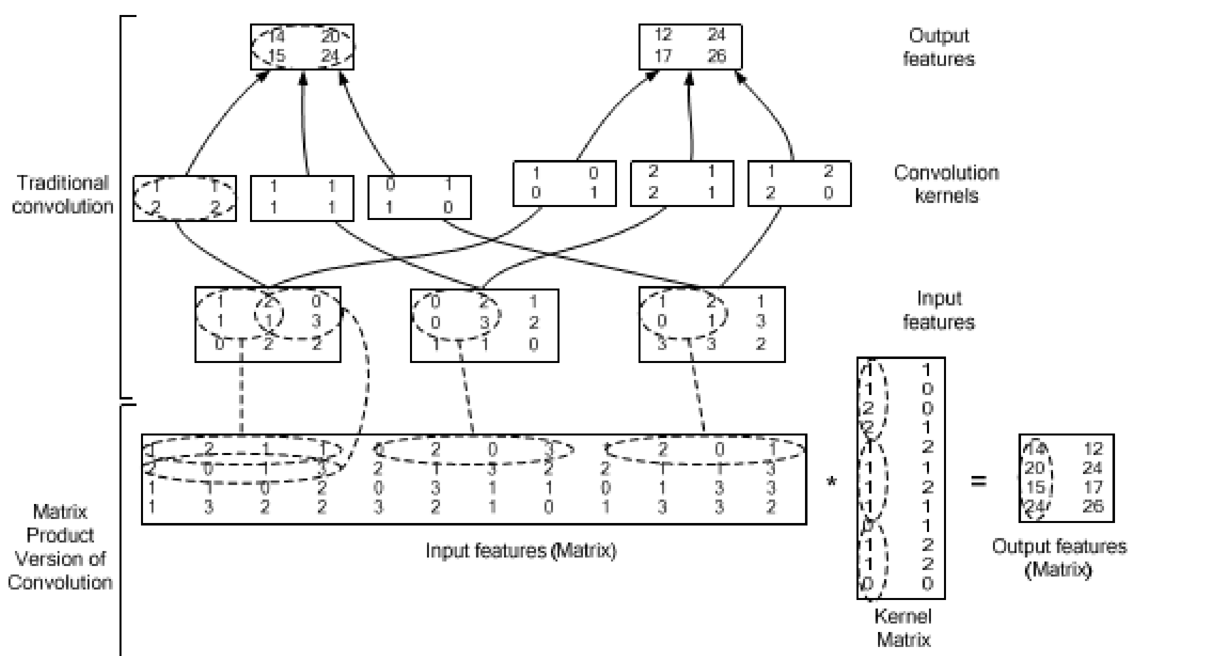

Figure 2. Example convolution operations in a convolutional layer (biases, sub-sampling, and non-linearity omitted). The top figure presents the traditional convolution operations, while the bottom figure presents the matrix version.

Convolutional Layer: im2col

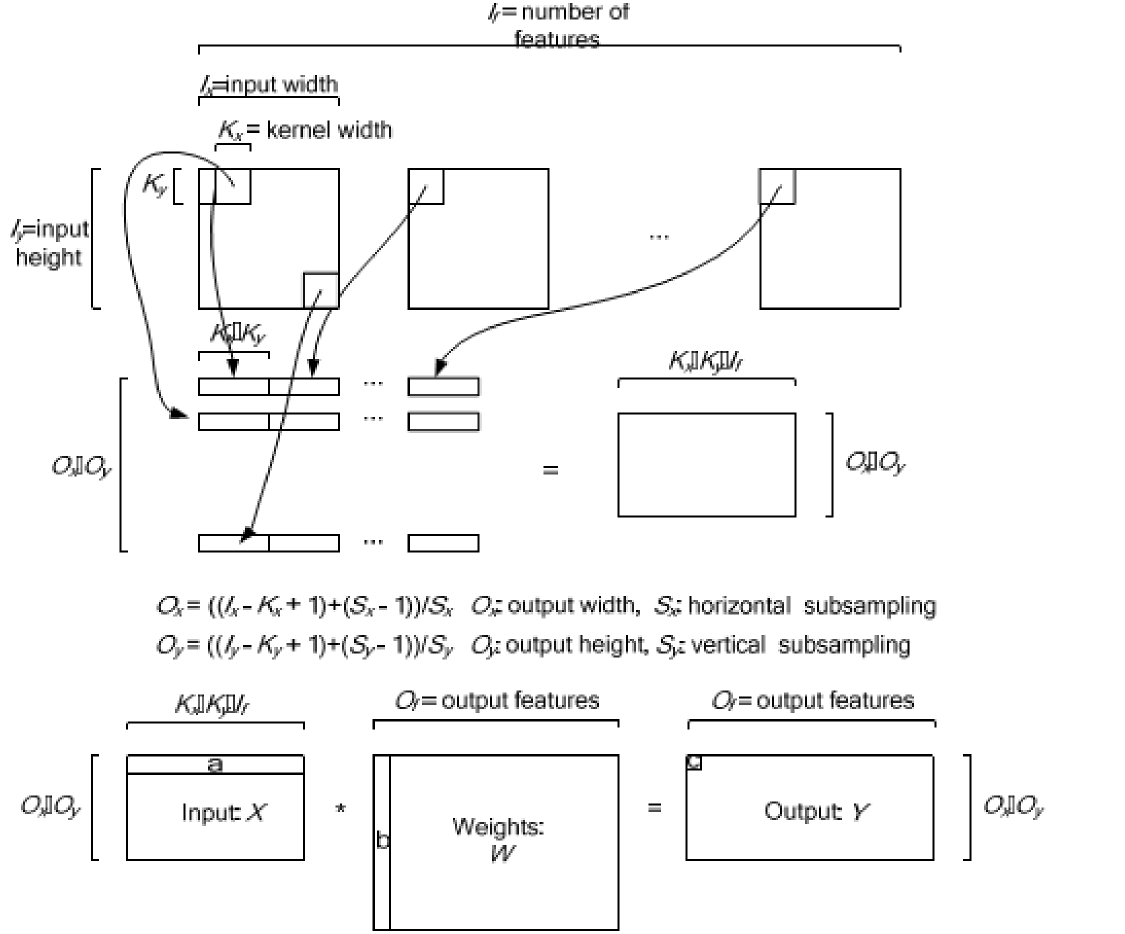

Figure 3. Unrolling the convolution operations in a convolutional layer (biases, sub-sampling, and non-linearity omitted), to produce a matrix-matrix product version.

Convolutional Layer: groups

AlexNet topology (Imagenet)

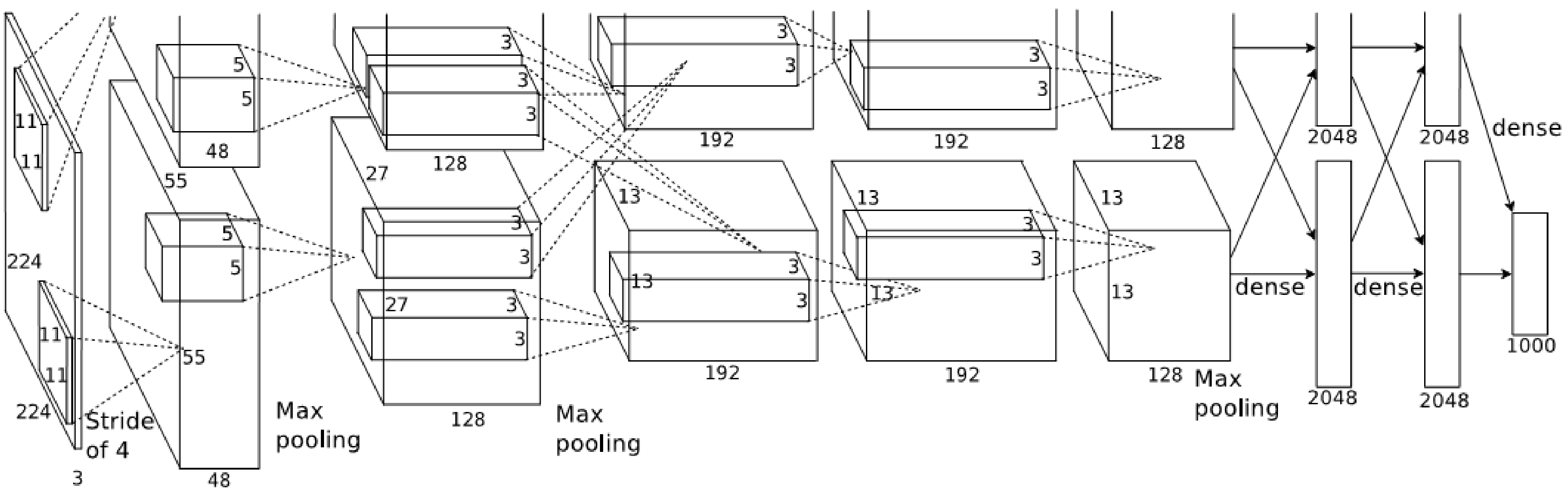

Figure 2: An illustration of the architecture of our CNN, explicitly showing the delineation of responsibilities between the two GPUs. One GPU runs the layer-parts at the top of the figure while the other runs the layer-parts at the bottom. The GPUs communicate only at certain layers. The network's input is 150,528-dimensional, and the number of neurons in the network's remaining layers is given by 253,440–186,624–64,896–64,896–43,264–4096–4096–1000.

Exercises

1. Play with Mnist topologies
   – How does the net accuracy depend on topology?

2. Port one of datasets http://deeplearning.net/datasets :
   – NORB, SVHN, …
3. Look at the definition of following layers:
   – sigmoid, tanh, …