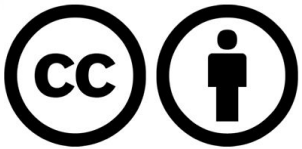
With TF 1.0!

Lab 11

CNN

Sung Kim <hunkim+ml@gmail.com>

Code: https://github.com/hunkim/DeepLearningZeroToAll/



Call for comments

Please feel free to add comments directly on these slides

Other slides: https://goo.gl/jPtWNt

Picture from http://www.tssablog.org/archives/3280

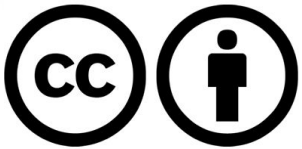
With TF 1.0!

Lab 11-1

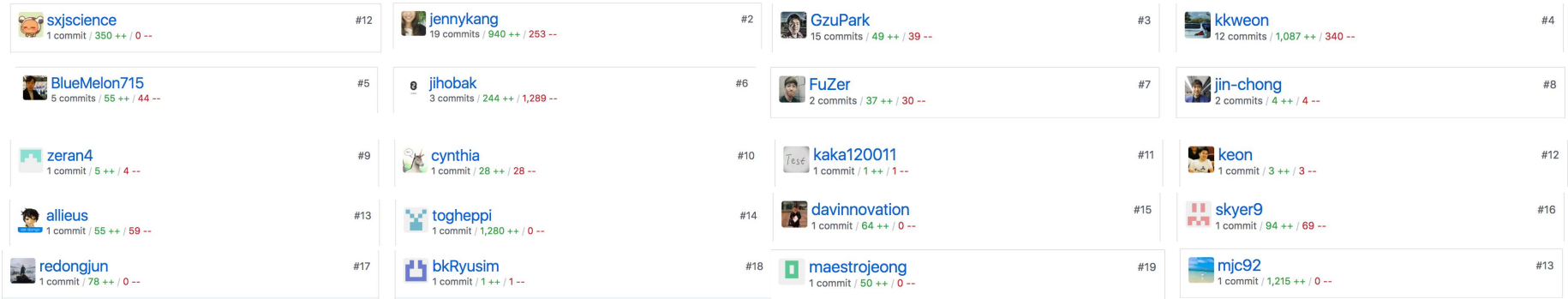
CNN Basics

Sung Kim <hunkim+ml@gmail.com>

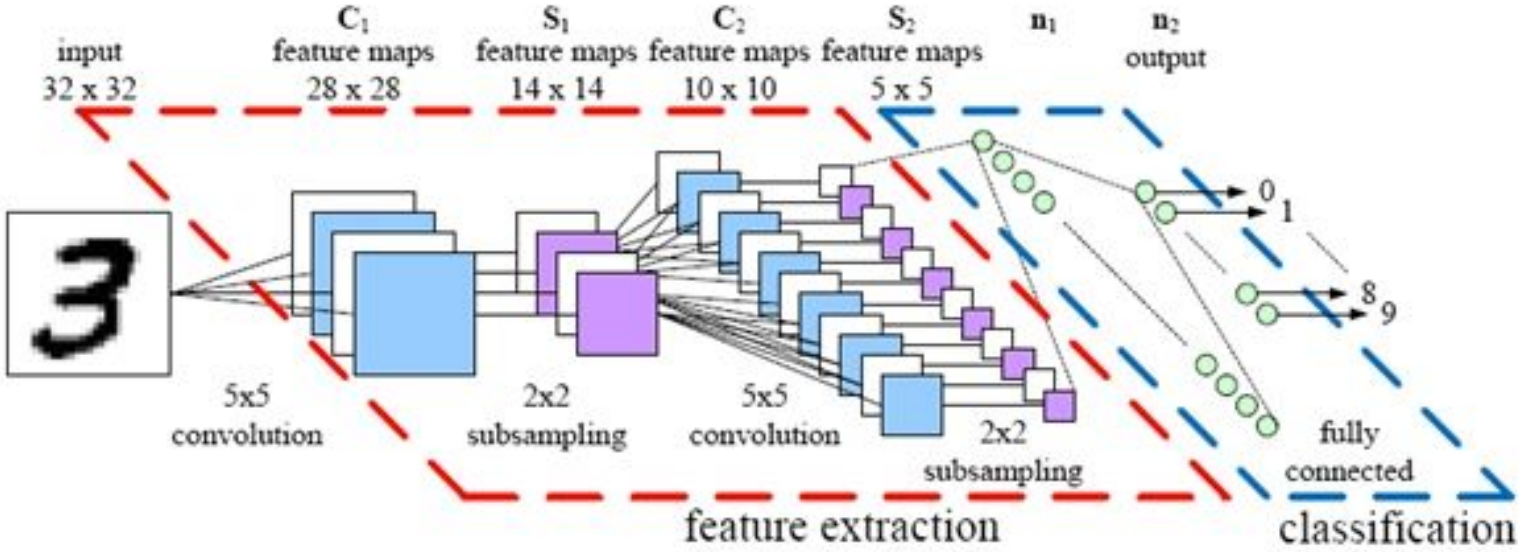
Code: https://github.com/hunkim/DeepLearningZeroToAll/



https://github.com/hunkim/DeepLearningZeroToAll/

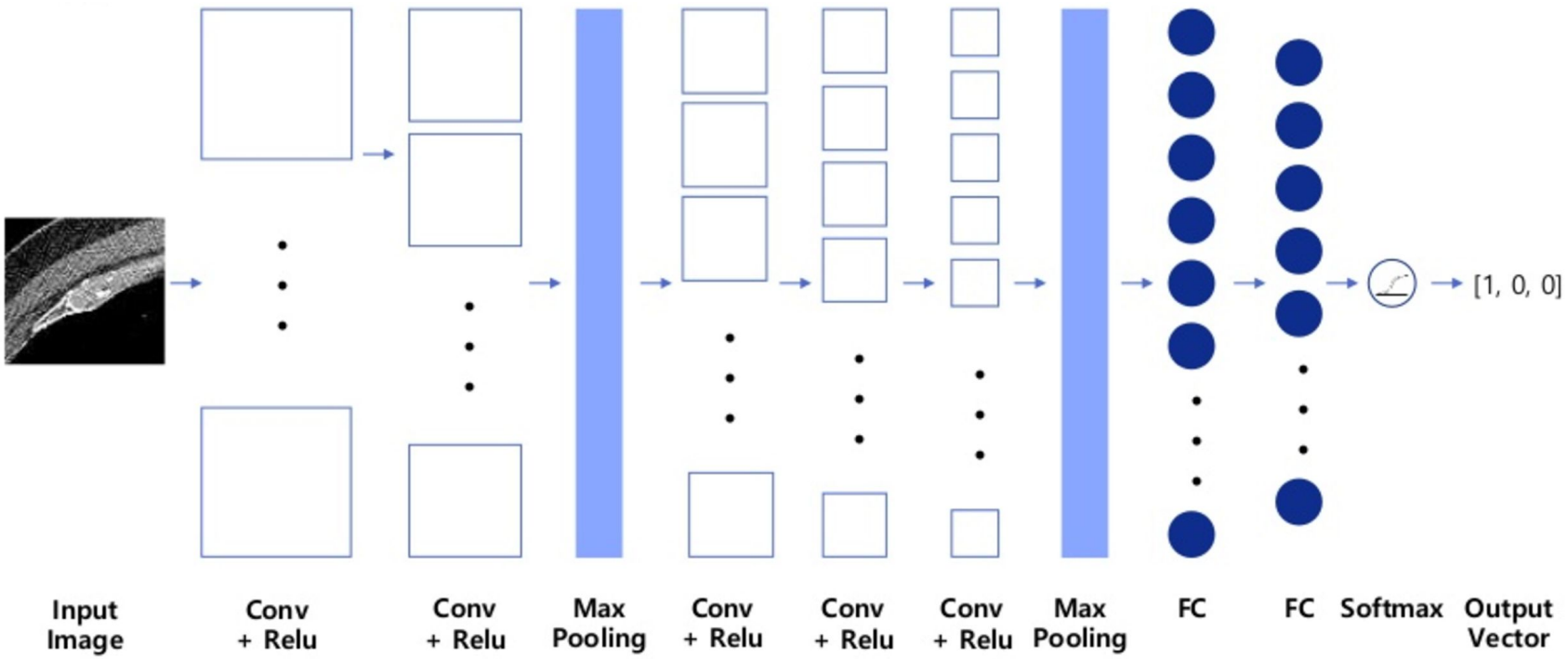


CNN



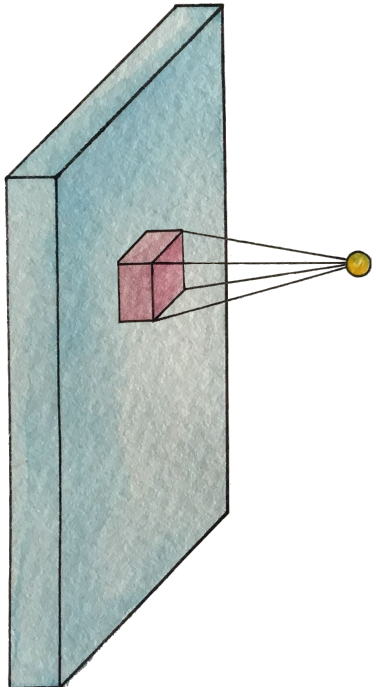
http://parse.ele.tue.nl/cluster/2/CNNArchitecture.jpg

CNN for CT images



Asan Medical Center & Microsoft Medical Bigdata Contest Winner by GeunYoung Lee and Alex Kim
https://www.slideshare.net/GYLee3/ss-72966495

Convolution layer and max pooling



Single depth slice

x

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

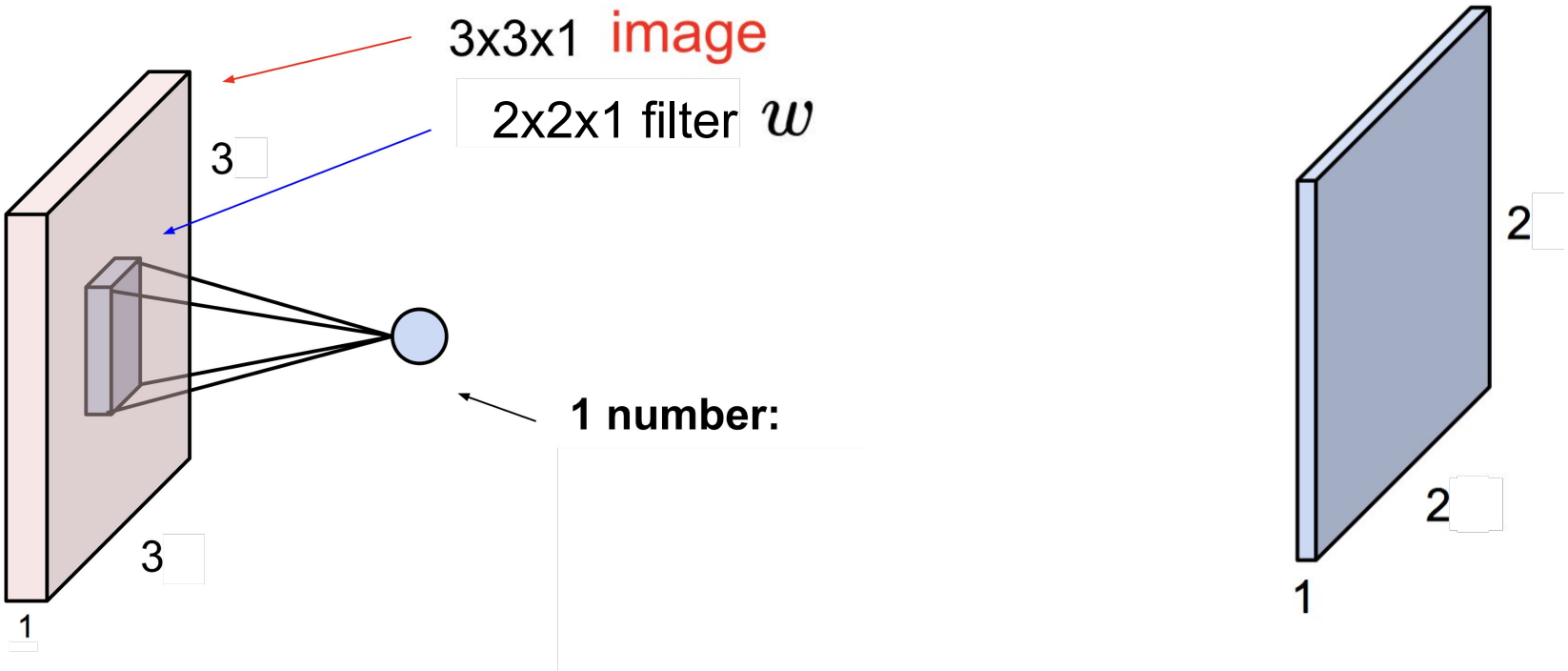
y

max pool with 2x2 filters
and stride 2

6	8
3	4

Simple convolution layer

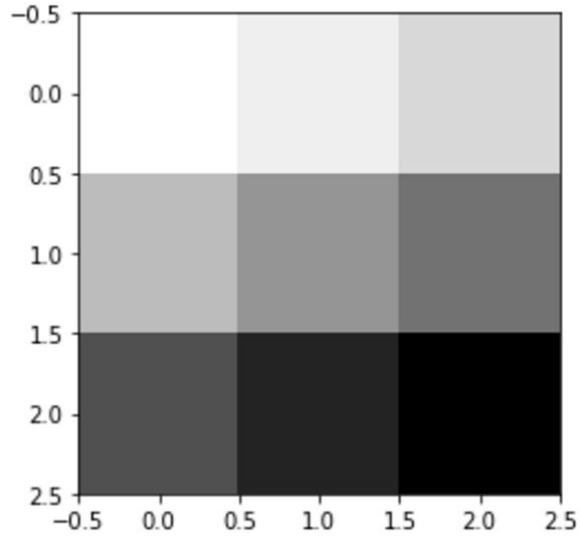
`Stride: 1x1`



In [2]:
```
sess = tf.InteractiveSession()
image = np.array([[[[1],[2],[3]],
                   [[4],[5],[6]],
                   [[7],[8],[9]]]], dtype=np.float32)
print(image.shape)
plt.imshow(image.reshape(3,3), cmap='Greys')
```

```
(1, 3, 3, 1)
```

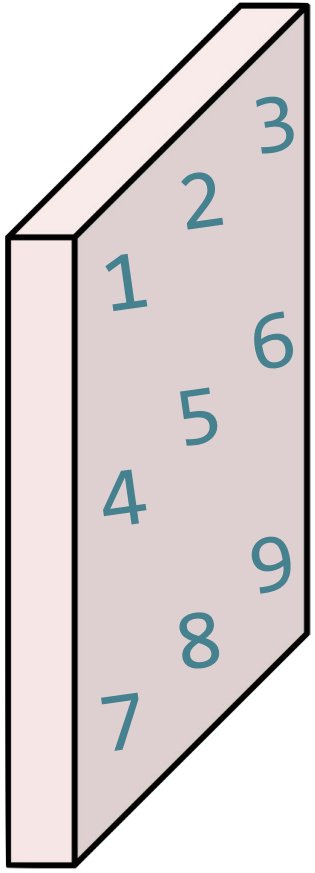
Out[2]: <matplotlib.image.AxesImage at 0x10db67dd8>

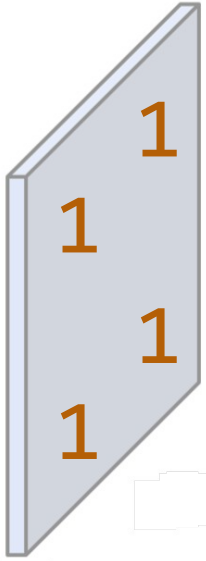


Toy image

Simple convolution layer

Image: 1,3,3,1 image, Filter: 2,2,1,1, Stride: 1x1, Padding: VALID






```
[[[[1.]],[[1.]]],
 [[[1.]],[[1.]]]]
shape=(2,2,1,1)
```

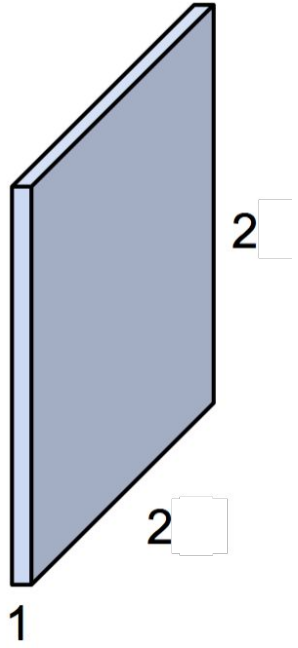
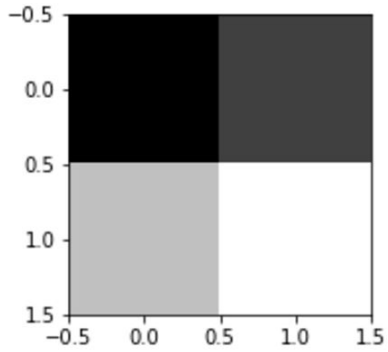
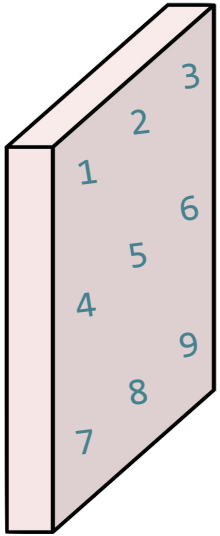


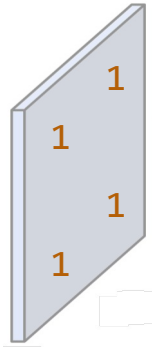
Image: 1,3,3,1 image, Filter: 2,2,1,1, Stride: 1x1, Padding: VALID

```
# print("imag:\n", image)
print("image.shape", image.shape)
weight = tf.constant([[[[1.]],[[1.]]],
                      [[[1.]],[[1.]]]])
print("weight.shape", weight.shape)
conv2d = tf.nn.conv2d(image, weight, strides=[1, 1, 1, 1], padding='VALID')
conv2d_img = conv2d.eval()
print("conv2d_img.shape", conv2d_img.shape)
conv2d_img = np.swapaxes(conv2d_img, 0, 3)
for i, one_img in enumerate(conv2d_img):
    print(one_img.reshape(2,2))
    plt.subplot(1,2,i+1), plt.imshow(one_img.reshape(2,2), cmap='gray')
```

```
image.shape (1, 3, 3, 1)
weight.shape (2, 2, 1, 1)
conv2d_img.shape (1, 2, 2, 1)
[[ 12.  16.]
 [ 24.  28.]]
```

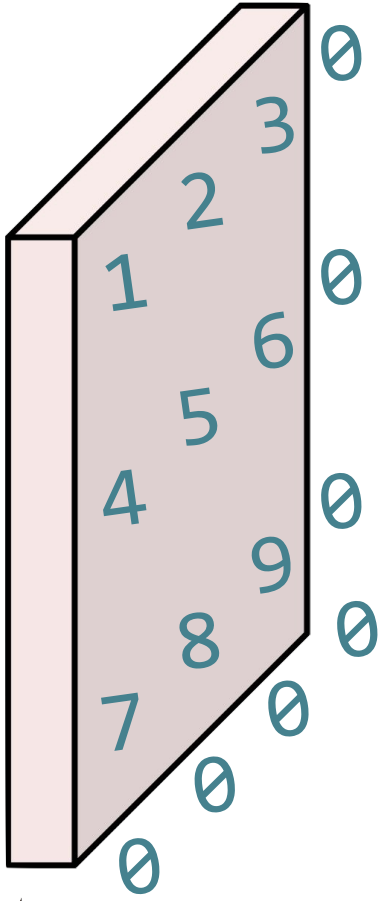


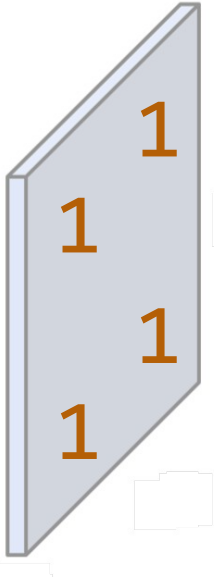




Simple convolution layer

Image: 1,3,3,1 image, Filter: 2,2,1,1, Stride: 1x1, Padding: **SAME**





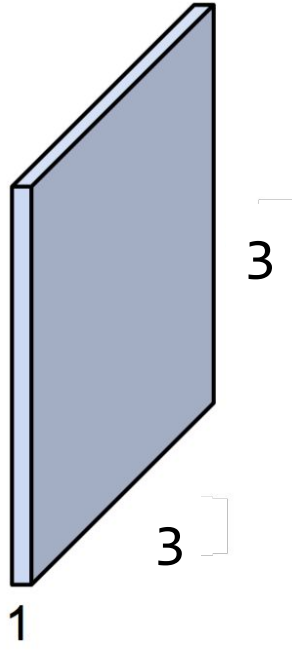
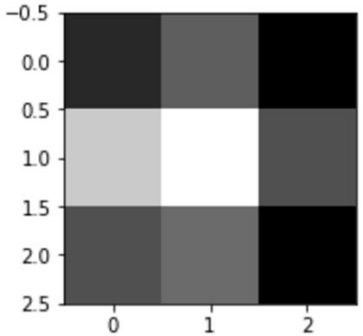


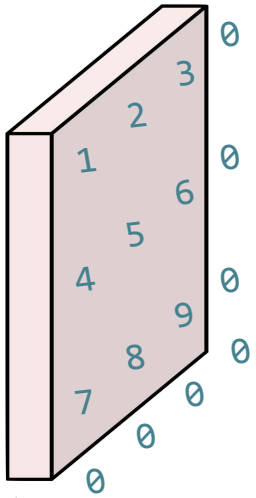
Image: 1,3,3,1 image, Filter: 2,2,1,1, Stride: 1x1, Padding: SAME

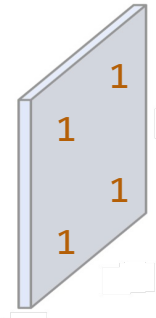
```
# print("imag:\n", image)
print("image.shape", image.shape)

weight = tf.constant([[[[1.]],[[1.]]],
                      [[[1.]],[[1.]]]])
print("weight.shape", weight.shape)
conv2d = tf.nn.conv2d(image, weight, strides=[1, 1, 1, 1], padding='SAME')
conv2d_img = conv2d.eval()
print("conv2d_img.shape", conv2d_img.shape)
conv2d_img = np.swapaxes(conv2d_img, 0, 3)
for i, one_img in enumerate(conv2d_img):
    print(one_img.reshape(3,3))
    plt.subplot(1,2,i+1), plt.imshow(one_img.reshape(3,3), cmap='gray')
```

```
image.shape (1, 3, 3, 1)
weight.shape (2, 2, 1, 1)
conv2d_img.shape (1, 3, 3, 1)
[[ 12.  16.   9.]
 [ 24.  28.  15.]
 [ 15.  17.   9.]]
```





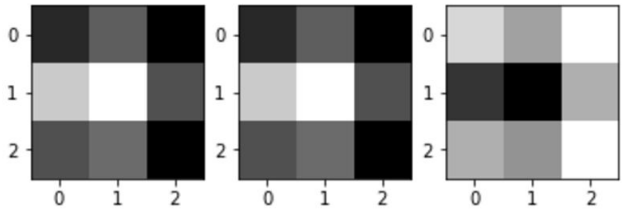


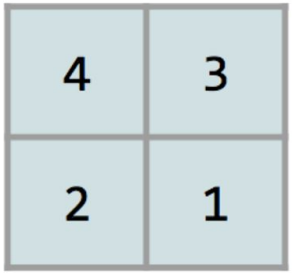
3 filters (2,2,1,3)

```
# print("imag:\n", image)
print("image.shape", image.shape)

weight = tf.constant([[[[1.,10.,-1.]],[[1.,10.,-1.]]],
                      [[[1.,10.,-1.]],[[1.,10.,-1.]]]])
print("weight.shape", weight.shape)
conv2d = tf.nn.conv2d(image, weight, strides=[1, 1, 1, 1], padding='SAME')
conv2d_img = conv2d.eval()
print("conv2d_img.shape", conv2d_img.shape)
conv2d_img = np.swapaxes(conv2d_img, 0, 3)
for i, one_img in enumerate(conv2d_img):
    print(one_img.reshape(3,3))
    plt.subplot(1,3,i+1), plt.imshow(one_img.reshape(3,3), cmap='gray')
```

```
image.shape (1, 3, 3, 1)
weight.shape (2, 2, 1, 3)
conv2d_img.shape (1, 3, 3, 3)
[[ 12.  16.   9.]
 [ 24.  28.  15.]
 [ 15.  17.   9.]]
[[ 120.  160.   90.]
 [ 240.  280.  150.]
 [ 150.  170.   90.]]
[[-12. -16.  -9.]
 [-24. -28. -15.]
 [-15. -17.  -9.]]
```





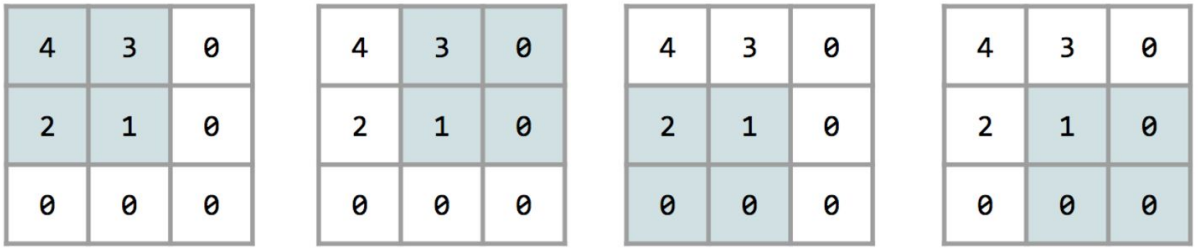
Max Pooling

In [19]:
```
image = np.array([[[[4],[3]],
                  [[2],[1]]]], dtype=np.float32)
pool = tf.nn.max_pool(image, ksize=[1, 2, 2, 1],
                      strides=[1, 1, 1, 1], padding='SAME')
print(pool.shape)
print(pool.eval())
```

```
(1, 2, 2, 1)
[[[[ 4.]
   [ 3.]]

  [[ 2.]
   [ 1.]]]]
```

SAME: Zero paddings



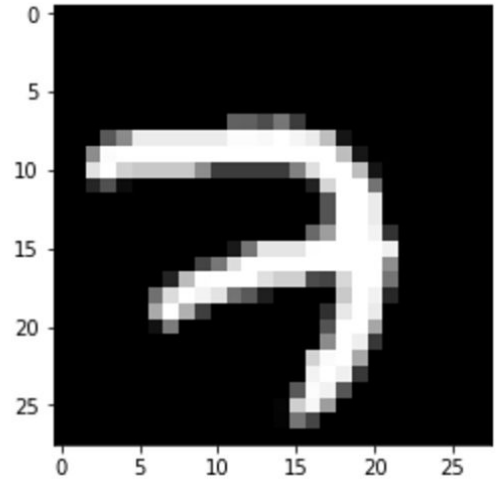
https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-0-cnn_basics.ipynb

In [6]:
```
from tensorflow.examples.tutorials.mnist import input_data
mnist = input_data.read_data_sets("MNIST_data/", one_hot=True)
# Check out https://www.tensorflow.org/get_started/mnist/beginners for
# more information about the mnist dataset
```

```
Extracting MNIST_data/train-images-idx3-ubyte.gz
Extracting MNIST_data/train-labels-idx1-ubyte.gz
Extracting MNIST_data/t10k-images-idx3-ubyte.gz
Extracting MNIST_data/t10k-labels-idx1-ubyte.gz
```

In [7]:
```
img = mnist.train.images[0].reshape(28,28)
plt.imshow(img, cmap='gray')
```

Out[7]:
```
<matplotlib.image.AxesImage at 0x115029ac8>
```



MNIST image loading

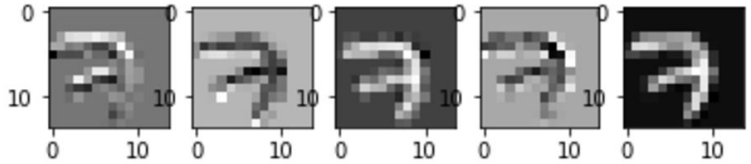
https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-0-cnn_basics.ipynb

MNIST Convolution layer

In [8]:
```
sess = tf.InteractiveSession()

img = img.reshape(-1,28,28,1)
W1 = tf.Variable(tf.random_normal([3, 3, 1, 5], stddev=0.01))
conv2d = tf.nn.conv2d(img, W1, strides=[1, 2, 2, 1], padding='SAME')
print(conv2d)
sess.run(tf.global_variables_initializer())
conv2d_img = conv2d.eval()
conv2d_img = np.swapaxes(conv2d_img, 0, 3)
for i, one_img in enumerate(conv2d_img):
    plt.subplot(1,5,i+1), plt.imshow(one_img.reshape(14,14), cmap='gray')
```

```
Tensor("Conv2D_1:0", shape=(1, 14, 14, 5), dtype=float32)
```

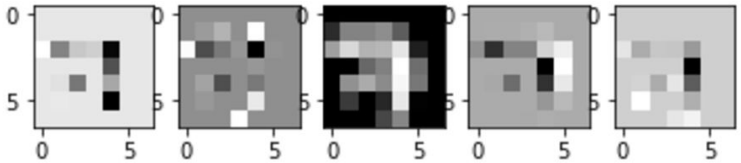


https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-0-cnn_basics.ipynb

MNIST Max pooling

In [9]:
```
pool = tf.nn.max_pool(conv2d, ksize=[1, 2, 2, 1], strides=[
                      1, 2, 2, 1], padding='SAME')
print(pool)
sess.run(tf.global_variables_initializer())
pool_img = pool.eval()
pool_img = np.swapaxes(pool_img, 0, 3)
for i, one_img in enumerate(pool_img):
    plt.subplot(1,5,i+1), plt.imshow(one_img.reshape(7, 7), cmap='gray')
```

```
Tensor("MaxPool_2:0", shape=(1, 7, 7, 5), dtype=float32)
```



https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-0-cnn_basics.ipynb

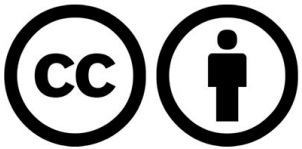
With TF 1.0!

Lab 11-2

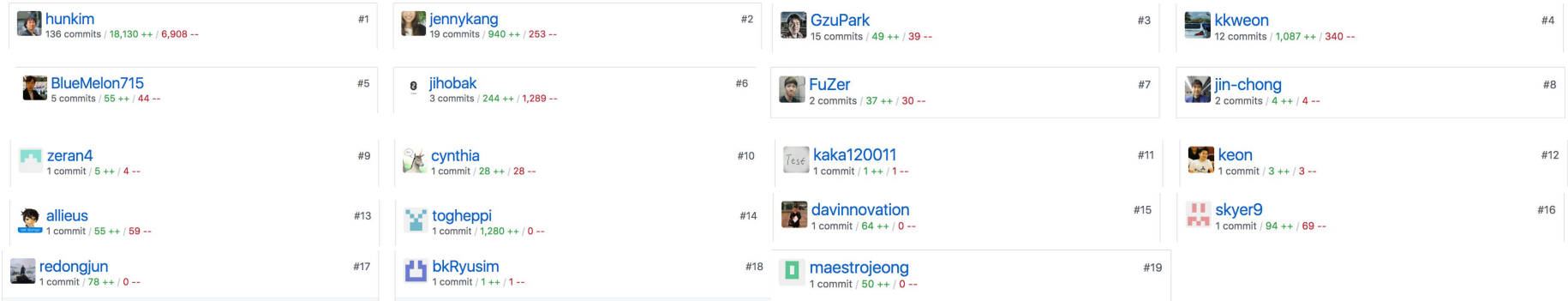
CNN MNIST: 99%!

Sung Kim <hunkim+ml@gmail.com>

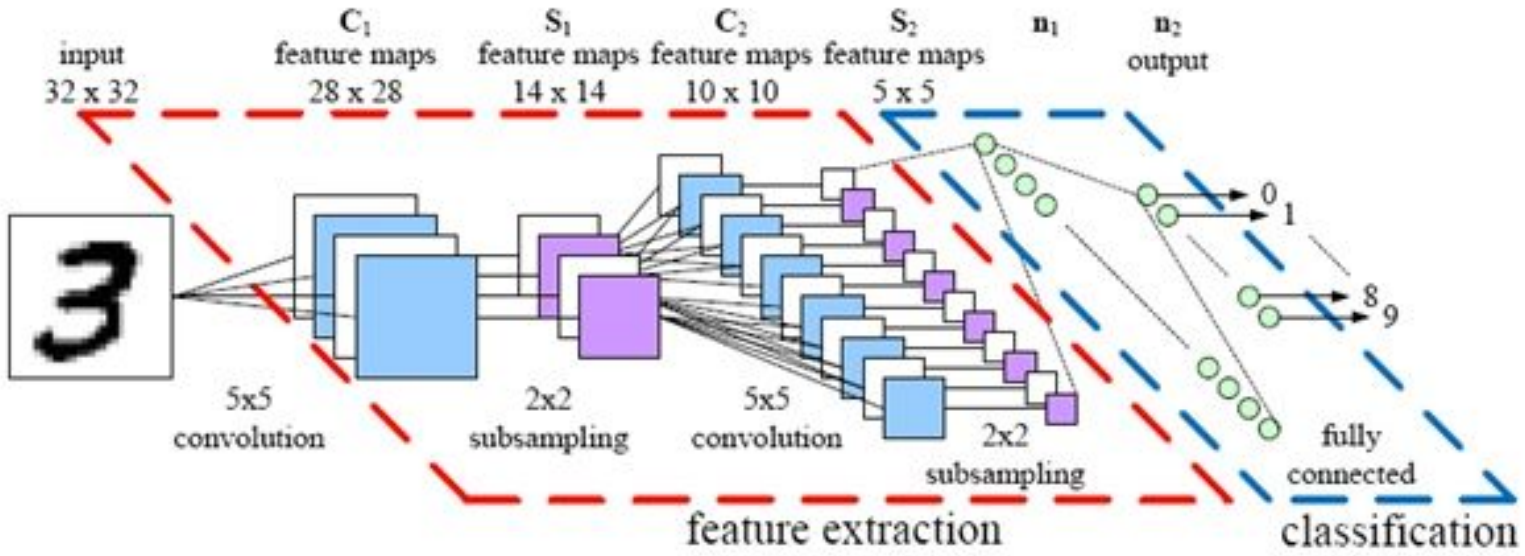
Code: https://github.com/hunkim/DeepLearningZeroToAll/



https://github.com/hunkim/DeepLearningZeroToAll/

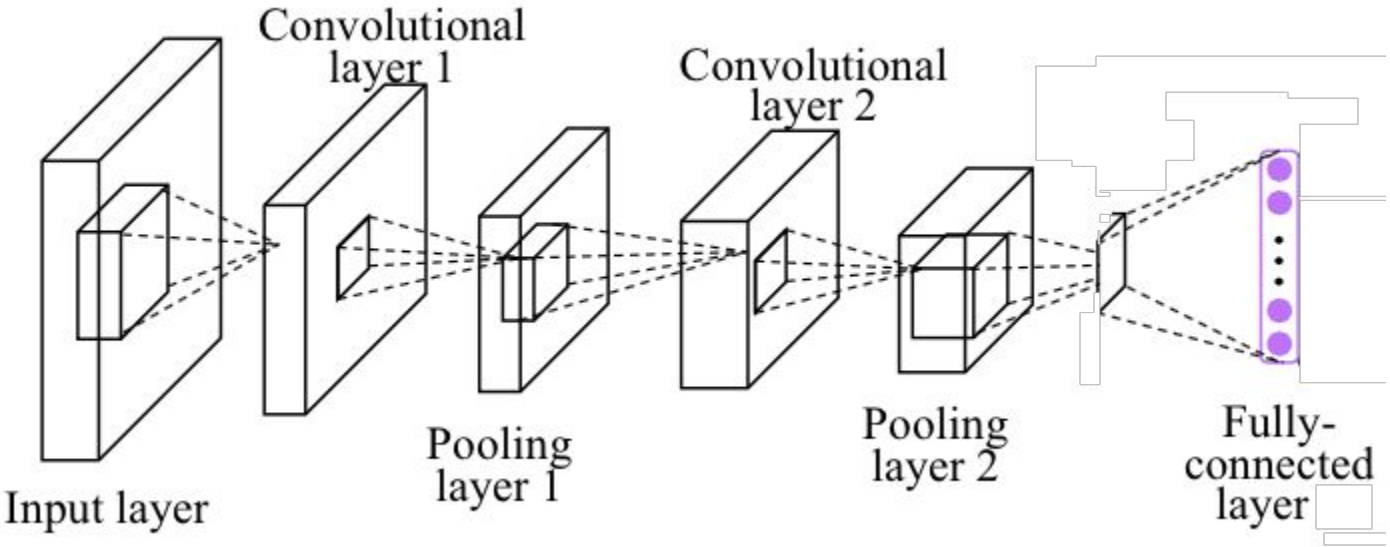


CNN

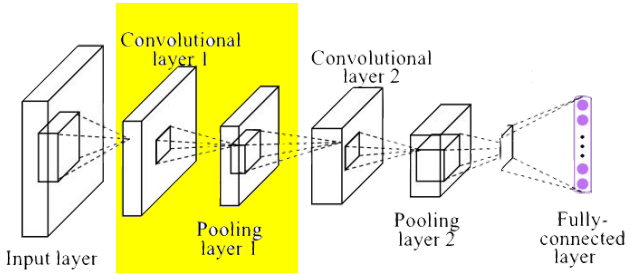


http://parse.ele.tue.nl/cluster/2/CNNArchitecture.jpg

Simple CNN


Convolutional layer 1
Convolutional layer 2
Input layer
Pooling layer 1
Pooling layer 2
Fully-connected layer

Conv layer 1

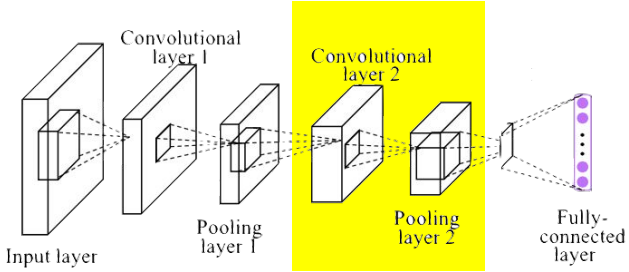



```
# input placeholders
X = tf.placeholder(tf.float32, [None, 784])
X_img = tf.reshape(X, [-1, 28, 28, 1])   # img 28x28x1 (black/white)
Y = tf.placeholder(tf.float32, [None, 10])

# L1 ImgIn shape=(?, 28, 28, 1)
W1 = tf.Variable(tf.random_normal([3, 3, 1, 32], stddev=0.01))
#    Conv     -> (?, 28, 28, 32)
#    Pool     -> (?, 14, 14, 32)
L1 = tf.nn.conv2d(X_img, W1, strides=[1, 1, 1, 1], padding='SAME')
L1 = tf.nn.relu(L1)
L1 = tf.nn.max_pool(L1, ksize=[1, 2, 2, 1],
         strides=[1, 2, 2, 1], padding='SAME')
'''
Tensor("Conv2D:0", shape=(?, 28, 28, 32), dtype=float32)
Tensor("Relu:0", shape=(?, 28, 28, 32), dtype=float32)
Tensor("MaxPool:0", shape=(?, 14, 14, 32), dtype=float32)
'''
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-1-mnist_cnn.py

Conv layer 2




```
'''
Tensor("Conv2D:0", shape=(?, 28, 28, 32), dtype=float32)
Tensor("Relu:0", shape=(?, 28, 28, 32), dtype=float32)
Tensor("MaxPool:0", shape=(?, 14, 14, 32), dtype=float32)
'''


# L2 ImgIn shape=(?, 14, 14, 32)
W2 = tf.Variable(tf.random_normal([3, 3, 32, 64], stddev=0.01))
#    Conv      ->(?, 14, 14, 64)
#    Pool      ->(?, 7, 7, 64)
L2 = tf.nn.conv2d(L1, W2, strides=[1, 1, 1, 1], padding='SAME')
L2 = tf.nn.relu(L2)
L2 = tf.nn.max_pool(L2, ksize=[1, 2, 2, 1], strides=[1, 2, 2, 1], padding='SAME')
L2 = tf.reshape(L2, [-1, 7 * 7 * 64])
'''
Tensor("Conv2D_1:0", shape=(?, 14, 14, 64), dtype=float32)
Tensor("Relu_1:0", shape=(?, 14, 14, 64), dtype=float32)
Tensor("MaxPool_1:0", shape=(?, 7, 7, 64), dtype=float32)
Tensor("Reshape_1:0", shape=(?, 3136), dtype=float32)
```

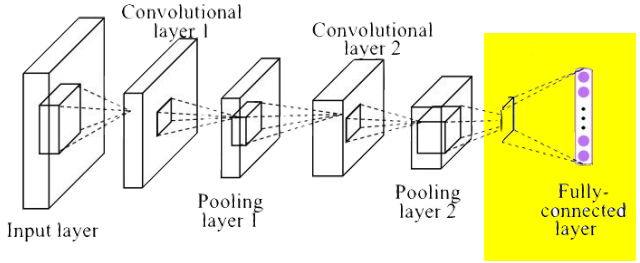
https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-1-mnist_cnn.py

Fully Connected (FC, Dense) layer

```
'''
Tensor("Conv2D_1:0", shape=(?, 14, 14, 64), dtype=float32)
Tensor("Relu_1:0", shape=(?, 14, 14, 64), dtype=float32)
Tensor("MaxPool_1:0", shape=(?, 7, 7, 64), dtype=float32)
Tensor("Reshape_1:0", shape=(?, 3136), dtype=float32)
'''
L2 = tf.reshape(L2, [-1, 7 * 7 * 64])

# Final FC 7x7x64 inputs -> 10 outputs
W3 = tf.get_variable("W3", shape=[7 * 7 * 64, 10],
initializer=tf.contrib.layers.xavier_initializer())
b = tf.Variable(tf.random_normal([10]))
hypothesis = tf.matmul(L2, W3) + b

# define cost/loss & optimizer
cost = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(logits=hypothesis, labels=Y))
optimizer = tf.train.AdamOptimizer(learning_rate=learning_rate).minimize(cost)
```



https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-1-mnist_cnn.py

Training and Evaluation

```
# initialize
sess = tf.Session()
sess.run(tf.global_variables_initializer())

# train my model
print('Learning stared. It takes sometime.')
for epoch in range(training_epochs):
    avg_cost = 0
    total_batch = int(mnist.train.num_examples / batch_size)
    for i in range(total_batch):
        batch_xs, batch_ys = mnist.train.next_batch(batch_size)
        feed_dict = {X: batch_xs, Y: batch_ys}
        c, _, = sess.run([cost, optimizer], feed_dict=feed_dict)
        avg_cost += c / total_batch
    print('Epoch:', '%04d' % (epoch + 1), 'cost =', '{:.9f}'.format(avg_cost))

print('Learning Finished!')

# Test model and check accuracy
correct_prediction = tf.equal(tf.argmax(hypothesis, 1), tf.argmax(Y, 1))
accuracy = tf.reduce_mean(tf.cast(correct_prediction, tf.float32))
print('Accuracy:', sess.run(accuracy, feed_dict={X: mnist.test.images, Y: mnist.test.labels}))
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-1-mnist_cnn.py

Training and Evaluation

```
# initialize
sess = tf.Session()
sess.run(tf.global_variables_initializer())

# train my model
print('Learning stared. It takes sometime.')
for epoch in range(training_epochs):
    avg_cost = 0
    total_batch = int(mnist.train.num_examples / batch_size)
    for i in range(total_batch):
        batch_xs, batch_ys = mnist.train.next_batch(batch_size)
        feed_dict = {X: batch_xs, Y: batch_ys}
        c, _, = sess.run([cost, optimizer], feed_dict=feed_dict)
        avg_cost += c / total_batch
    print('Epoch:', '%04d' % (epoch + 1), 'cost =', '{:.9f}'.format(avg_cost))

print('Learning Finished!')

# Test model and check accuracy
correct_prediction = tf.equal(tf.argmax(hypothesis, 1), tf.argmax(Y, 1))
accuracy = tf.reduce_mean(tf.cast(correct_prediction, tf.float32))
print('Accuracy:', sess.run(accuracy, feed_dict={X: mnist.test.images, Y: mnist.test.labels}))
```

```
Epoch: 0001 cost = 0.340291267
Epoch: 0002 cost = 0.090731326
Epoch: 0003 cost = 0.064477619
Epoch: 0004 cost = 0.050683064
...
Epoch: 0011 cost = 0.017758641
Epoch: 0012 cost = 0.014156652
Epoch: 0013 cost = 0.012397016
Epoch: 0014 cost = 0.010693789
Epoch: 0015 cost = 0.009469977
Learning Finished!
Accuracy: 0.9885
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-1-mnist_cnn.py

Deep CNN

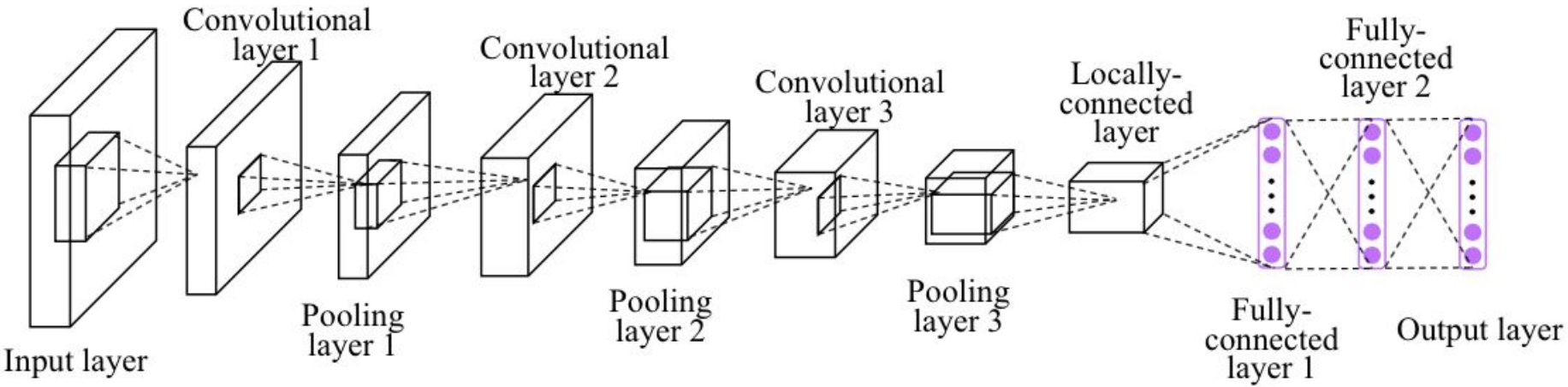


Image credit: http://personal.ie.cuhk.edu.hk/~ccloy/project_target_code/index.html

Deep CNN

```
# L1 ImgIn shape=(?, 28, 28, 1)
W1 = tf.Variable(tf.random_normal([3, 3, 1, 32], stddev=0.01))
#    Conv      -> (?, 28, 28, 32)
#    Pool      -> (?, 14, 14, 32)
L1 = tf.nn.conv2d(X_img, W1, strides=[1, 1, 1, 1], padding='SAME')
L1 = tf.nn.relu(L1)
L1 = tf.nn.max_pool(L1, ksize=[1, 2, 2, 1],
                    strides=[1, 2, 2, 1], padding='SAME')
L1 = tf.nn.dropout(L1, keep_prob=keep_prob)
'''Tensor("Conv2D:0", shape=(?, 28, 28, 32), dtype=float32)
   Tensor("Relu:0", shape=(?, 28, 28, 32), dtype=float32)
   Tensor("MaxPool:0", shape=(?, 14, 14, 32), dtype=float32)
   Tensor("dropout/mul:0", shape=(?, 14, 14, 32), dtype=float32)'''

# L2 ImgIn shape=(?, 14, 14, 32)
W2 = tf.Variable(tf.random_normal([3, 3, 32, 64], stddev=0.01))
#    Conv      ->(?, 14, 14, 64)
#    Pool      ->(?, 7, 7, 64)
L2 = tf.nn.conv2d(L1, W2, strides=[1, 1, 1, 1], padding='SAME')
L2 = tf.nn.relu(L2)
L2 = tf.nn.max_pool(L2, ksize=[1, 2, 2, 1],
                    strides=[1, 2, 2, 1], padding='SAME')
L2 = tf.nn.dropout(L2, keep_prob=keep_prob)
'''Tensor("Conv2D_1:0", shape=(?, 14, 14, 64), dtype=float32)
   Tensor("Relu_1:0", shape=(?, 14, 14, 64), dtype=float32)
   Tensor("MaxPool_1:0", shape=(?, 7, 7, 64), dtype=float32)
   Tensor("dropout_1/mul:0", shape=(?, 7, 7, 64), dtype=float32)'''
```

```
# L3 ImgIn shape=(?, 7, 7, 64)
W3 = tf.Variable(tf.random_normal([3, 3, 64, 128], stddev=0.01))
#    Conv      ->(?, 7, 7, 128)
#    Pool      ->(?, 4, 4, 128)
#    Reshape   ->(?, 4 * 4 * 128) # Flatten them for FC
L3 = tf.nn.conv2d(L2, W3, strides=[1, 1, 1, 1], padding='SAME')
L3 = tf.nn.relu(L3)
L3 = tf.nn.max_pool(L3, ksize=[1, 2, 2, 1], strides=[1, 2, 2, 1],
padding='SAME')
L3 = tf.nn.dropout(L3, keep_prob=keep_prob)
L3 = tf.reshape(L3, [-1, 128 * 4 * 4])
'''Tensor("Conv2D_2:0", shape=(?, 7, 7, 128), dtype=float32)
   Tensor("Relu_2:0", shape=(?, 7, 7, 128), dtype=float32)
   Tensor("MaxPool_2:0", shape=(?, 4, 4, 128), dtype=float32)
   Tensor("dropout_2/mul:0", shape=(?, 4, 4, 128), dtype=float32)
   Tensor("Reshape_1:0", shape=(?, 2048), dtype=float32)'''
# L4 FC 4x4x128 inputs -> 625 outputs
W4 = tf.get_variable("W4", shape=[128 * 4 * 4, 625],
initializer=tf.contrib.layers.xavier_initializer())
b4 = tf.Variable(tf.random_normal([625]))
L4 = tf.nn.relu(tf.matmul(L3, W4) + b4)
L4 = tf.nn.dropout(L4, keep_prob=keep_prob)
'''Tensor("Relu_3:0", shape=(?, 625), dtype=float32)
   Tensor("dropout_3/mul:0", shape=(?, 625), dtype=float32)'''
# L5 Final FC 625 inputs -> 10 outputs
W5 = tf.get_variable("W5", shape=[625, 10],
initializer=tf.contrib.layers.xavier_initializer())
b5 = tf.Variable(tf.random_normal([10]))
hypothesis = tf.matmul(L4, W5) + b5
'''Tensor("add_1:0", shape=(?, 10), dtype=float32)'''
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-2-mnist_deep_cnn.py

Deep CNN

```
# L1 ImgIn shape=(?, 28, 28, 1)
W1 = tf.Variable(tf.random_normal([3, 3, 1, 32], stddev=0.01))
#    Conv     -> (?, 28, 28, 32)
#    Pool     -> (?, 14, 14, 32)
L1 = tf.nn.conv2d(X_img, W1, strides=[1, 1, 1, 1], padding='SAME')
L1 = tf.nn.relu(L1)
L1 = tf.nn.max_pool(L1, ksize=[1, 2, 2, 1],
                    strides=[1, 2, 2, 1], padding='SAME')
L1 = tf.nn.dropout(L1, keep_prob=keep_prob)
'''Tensor("Conv2D:0", shape=(?, 28, 28, 32), dtype=float32)
   Tensor("Relu:0", shape=(?, 28, 28, 32), dtype=float32)
   Tensor("MaxPool:0", shape=(?, 14, 14, 32), dtype=float32)
   Tensor("dropout/mul:0", shape=(?, 14, 14, 32), dtype=float32)'''
...
...
# L4 FC 4x4x128 inputs -> 625 outputs
W4 = tf.get_variable("W4", shape=[128 * 4 * 4, 625],
initializer=tf.contrib.layers.xavier_initializer())
b4 = tf.Variable(tf.random_normal([625]))
L4 = tf.nn.relu(tf.matmul(L3, W4) + b4)
L4 = tf.nn.dropout(L4, keep_prob=keep_prob)
'''Tensor("Relu_3:0", shape=(?, 625), dtype=float32)
   Tensor("dropout_3/mul:0", shape=(?, 625), dtype=float32)'''
# L5 Final FC 625 inputs -> 10 outputs
W5 = tf.get_variable("W5", shape=[625, 10],
initializer=tf.contrib.layers.xavier_initializer())
b5 = tf.Variable(tf.random_normal([10]))
hypothesis = tf.matmul(L4, W5) + b5
'''Tensor("add_1:0", shape=(?, 10), dtype=float32)'''
```

```
# Test model and check accuracy
correct_prediction = tf.equal(tf.argmax(hypothesis, 1),
         tf.argmax(Y, 1))
accuracy =
tf.reduce_mean(tf.cast(correct_prediction,tf.float32))
print('Accuracy:', sess.run(accuracy,
feed_dict={X: mnist.test.images,
           Y: mnist.test.labels, keep_prob: 1}))
```

```
Epoch: 0013 cost = 0.027188021
Epoch: 0014 cost = 0.023604777
Epoch: 0015 cost = 0.024607201
Learning Finished!

Accuracy: 0.9938
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-2-mnist_deep_cnn.py

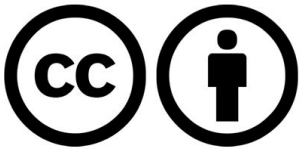
With TF 1.0!

Lab 11-3

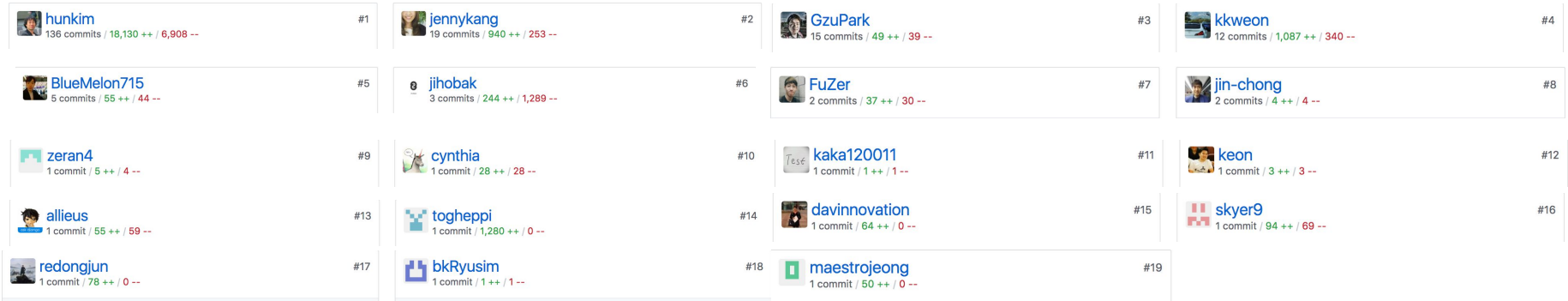
Class, Layers, Ensemble

Sung Kim <hunkim+ml@gmail.com>

Code: https://github.com/hunkim/DeepLearningZeroToAll/



https://github.com/hunkim/DeepLearningZeroToAll/



CNN

```
# L1 ImgIn shape=(?, 28, 28, 1)
W1 = tf.Variable(tf.random_normal([3, 3, 1, 32], stddev=0.01))
#    Conv     -> (?, 28, 28, 32)
#    Pool     -> (?, 14, 14, 32)
L1 = tf.nn.conv2d(X_img, W1, strides=[1, 1, 1, 1], padding='SAME')
L1 = tf.nn.relu(L1)
L1 = tf.nn.max_pool(L1, ksize=[1, 2, 2, 1],
                    strides=[1, 2, 2, 1], padding='SAME')
L1 = tf.nn.dropout(L1, keep_prob=keep_prob)
'''Tensor("Conv2D:0", shape=(?, 28, 28, 32), dtype=float32)
   Tensor("Relu:0", shape=(?, 28, 28, 32), dtype=float32)
   Tensor("MaxPool:0", shape=(?, 14, 14, 32), dtype=float32)
   Tensor("dropout/mul:0", shape=(?, 14, 14, 32), dtype=float32)'''
...
...
# L4 FC 4x4x128 inputs -> 625 outputs
W4 = tf.get_variable("W4", shape=[128 * 4 * 4, 625],
initializer=tf.contrib.layers.xavier_initializer())
b4 = tf.Variable(tf.random_normal([625]))
L4 = tf.nn.relu(tf.matmul(L3, W4) + b4)
L4 = tf.nn.dropout(L4, keep_prob=keep_prob)
'''Tensor("Relu_3:0", shape=(?, 625), dtype=float32)
   Tensor("dropout_3/mul:0", shape=(?, 625), dtype=float32)'''
# L5 Final FC 625 inputs -> 10 outputs
W5 = tf.get_variable("W5", shape=[625, 10],
initializer=tf.contrib.layers.xavier_initializer())
b5 = tf.Variable(tf.random_normal([10]))
hypothesis = tf.matmul(L4, W5) + b5
'''Tensor("add_1:0", shape=(?, 10), dtype=float32)'''
```

```
# Test model and check accuracy
correct_prediction = tf.equal(tf.argmax(hypothesis, 1),
         tf.argmax(Y, 1))
accuracy =
tf.reduce_mean(tf.cast(correct_prediction,tf.float32))
print('Accuracy:', sess.run(accuracy,
feed_dict={X: mnist.test.images,
           Y: mnist.test.labels, keep_prob: 1}))
```

```
Epoch: 0013 cost = 0.027188021
Epoch: 0014 cost = 0.023604777
Epoch: 0015 cost = 0.024607201
Learning Finished!
Accuracy: 0.9938
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-2-mnist_deep_cnn.py

Python Class

```python
class Model:

    def __init__(self, sess, name):
        self.sess = sess
        self.name = name
        self._build_net()

    def _build_net(self):
        with tf.variable_scope(self.name):
            # input place holders
            self.X = tf.placeholder(tf.float32, [None, 784])
            # img 28x28x1 (black/white)
            X_img = tf.reshape(self.X, [-1, 28, 28, 1])
            self.Y = tf.placeholder(tf.float32, [None, 10])

            # L1 ImgIn shape=(?, 28, 28, 1)
            W1 = tf.Variable(tf.random_normal([3, 3, 1, 32],
                                              stddev=0.01))
            ...
def predict(self, x_test, keep_prop=1.0):
    return self.sess.run(self.logits,
         feed_dict={self.X: x_test, self.keep_prob: keep_prop})

def get_accuracy(self, x_test, y_test, keep_prop=1.0):
    return self.sess.run(self.accuracy,
     feed_dict={self.X: x_test, self.Y: y_test, self.keep_prob: keep_prop})

def train(self, x_data, y_data, keep_prop=0.7):
    return self.sess.run([self.cost, self.optimizer], feed_dict={
        self.X: x_data, self.Y: y_data, self.keep_prob: keep_prop})
```

```python
# initialize
sess = tf.Session()
m1 = Model(sess, "m1")

sess.run(tf.global_variables_initializer())

print('Learning Started!')

# train my model
for epoch in range(training_epochs):
    avg_cost = 0
    total_batch = int(mnist.train.num_examples / batch_size)

    for i in range(total_batch):
        batch_xs, batch_ys = mnist.train.next_batch(batch_size)
        c, _ = m1.train(batch_xs, batch_ys)
        avg_cost += c / total_batc
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-3-mnist_cnn_class.py

tf.layers

`average_pooling1d(...)` : Average Pooling layer for 1D inputs.

`average_pooling2d(...)` : Average pooling layer for 2D inputs (e.g. images).

`average_pooling3d(...)` : Average pooling layer for 3D inputs (e.g. volumes).

`batch_normalization(...)` : Functional interface for the batch normalization layer.

`conv1d(...)` : Functional interface for 1D convolution layer (e.g. temporal convolution).

`conv2d(...)` : Functional interface for the 2D convolution layer.

`conv2d_transpose(...)` : Transposed convolution layer (sometimes called Deconvolution).

`conv3d(...)` : Functional interface for the 3D convolution layer.

`dense(...)` : Functional interface for the densely-connected layer.

`dropout(...)` : Applies Dropout to the input.

`max_pooling1d(...)` : Max Pooling layer for 1D inputs.

`max_pooling2d(...)` : Max pooling layer for 2D inputs (e.g. images).

`max_pooling3d(...)` : Max pooling layer for 3D inputs (e.g. volumes).

`separable_conv2d(...)` : Functional interface for the depthwise separable 2D convolution layer.

https://www.tensorflow.org/api_docs/python/tf/layers

tf.layers

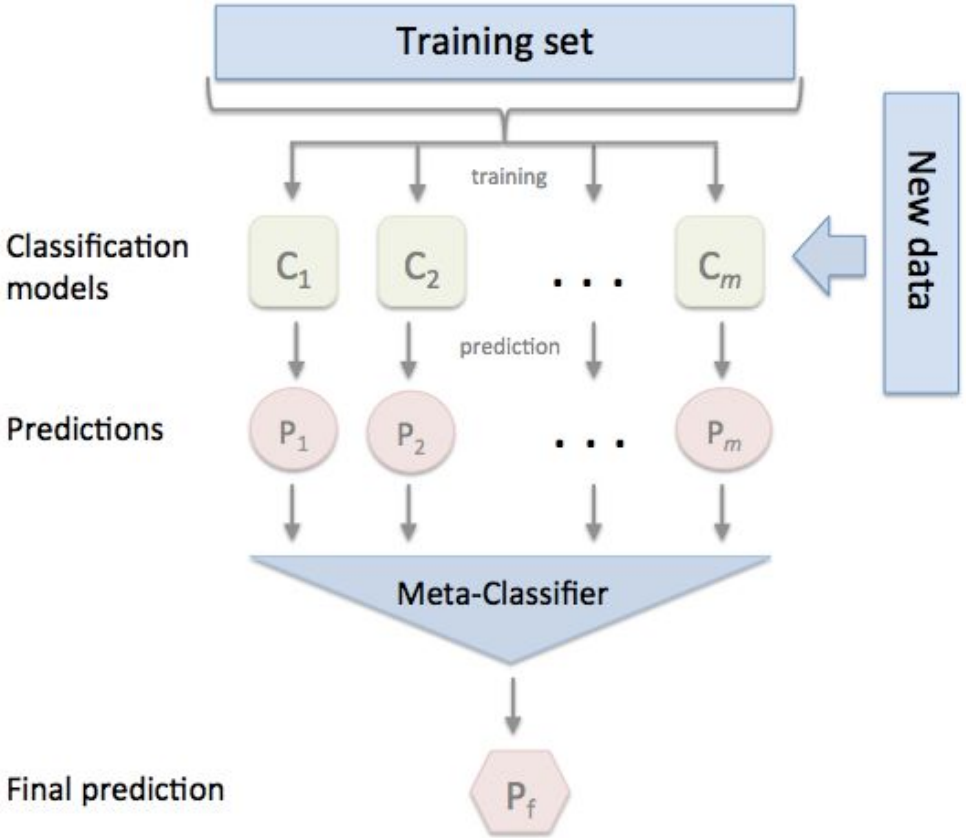
```
# L1 ImgIn shape=(?, 28, 28, 1)
W1 = tf.Variable(tf.random_normal([3, 3, 1, 32], stddev=0.01))
#    Conv     -> (?, 28, 28, 32)
#    Pool     -> (?, 14, 14, 32)
L1 = tf.nn.conv2d(X_img, W1, strides=[1, 1, 1, 1], padding='SAME')
L1 = tf.nn.relu(L1)
L1 = tf.nn.max_pool(L1, ksize=[1, 2, 2, 1], strides=[1, 2, 2, 1], padding='SAME')
L1 = tf.nn.dropout(L1, keep_prob=self.keep_prob)
...
# L2 ImgIn shape=(?, 14, 14, 32)
W2 = tf.Variable(tf.random_normal([3, 3, 32, 64], stddev=0.01))
```

```
# Convolutional Layer #1
conv1 = tf.layers.conv2d(inputs=X_img,filters=32,kernel_size=[3,3],padding="SAME",activation=tf.nn.relu)
pool1 = tf.layers.max_pooling2d(inputs=conv1, pool_size=[2, 2], padding="SAME", strides=2)
dropout1 = tf.layers.dropout(inputs=pool1,rate=0.7, training=self.training)

# Convolutional Layer #2
conv2 = tf.layers.conv2d(inputs=dropout1,filters=64,kernel_size=[3,3],padding="SAME",activation=tf.nn.relu)
...
flat = tf.reshape(dropout3, [-1, 128 * 4 * 4])
dense4 = tf.layers.dense(inputs=flat, units=625, activation=tf.nn.relu)
dropout4 = tf.layers.dropout(inputs=dense4, rate=0.5, training=self.training)
...
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-4-mnist_cnn_layers.py

Ensemble



http://rasbt.github.io/mlxtend/user_guide/classifier/StackingClassifier/

Ensemble training

```
class Model:

  def __init__(self, sess, name):
    self.sess = sess
    self.name = name
    self._build_net()

  def _build_net(self):
    with tf.variable_scope(self.name):

  ...
```

```
models = []
num_models = 7
for m in range(num_models):
    models.append(Model(sess, "model" + str(m)))

sess.run(tf.global_variables_initializer())
print('Learning Started!')

# train my model
for epoch in range(training_epochs):
    avg_cost_list = np.zeros(len(models))
    total_batch = int(mnist.train.num_examples / batch_size)
    for i in range(total_batch):
        batch_xs, batch_ys =mnist.train.next_batch(batch_size)

        # train each model
        for m_idx, m in enumerate(models):
            c, _ = m.train(batch_xs, batch_ys)
            avg_cost_list[m_idx] += c / total_batch

    print('Epoch:','%04d'%(epoch + 1),'cost =', avg_cost_list)

print('Learning Finished!')
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-5-mnist_cnn_ensemble_layers.py

Ensemble prediction

C_1

C_2

C_m

Ensemble prediction

	0	1	2	3	4	5	6	7	8	9
C_1 →	0.1	0.01	0.02	0.8	...	...	...	...	...	...
C_2 →	0.01	0.5	0.02	0.4	...	...	...	...	...	...
. . .										
C_m →	0.01	0.01	0.1	0.7	...	...	...	...	...	...
Sum	0.12	0.52	0.14	**1.9**	...	...	...	...	...	...

argmax

Ensemble prediction

```
# Test model and check accuracy
test_size = len(mnist.test.labels)
predictions = np.zeros(test_size * 10).reshape(test_size, 10)


for m_idx, m in enumerate(models):
    print(m_idx, 'Accuracy:', m.get_accuracy(mnist.test.images, mnist.test.labels))
    p = m.predict(mnist.test.images)
    predictions += p

ensemble_correct_prediction = tf.equal(
     tf.argmax(predictions, 1), tf.argmax(mnist.test.labels, 1))
ensemble_accuracy = tf.reduce_mean(
    tf.cast(ensemble_correct_prediction, tf.float32))
print('Ensemble accuracy:', sess.run(ensemble_accuracy))
```

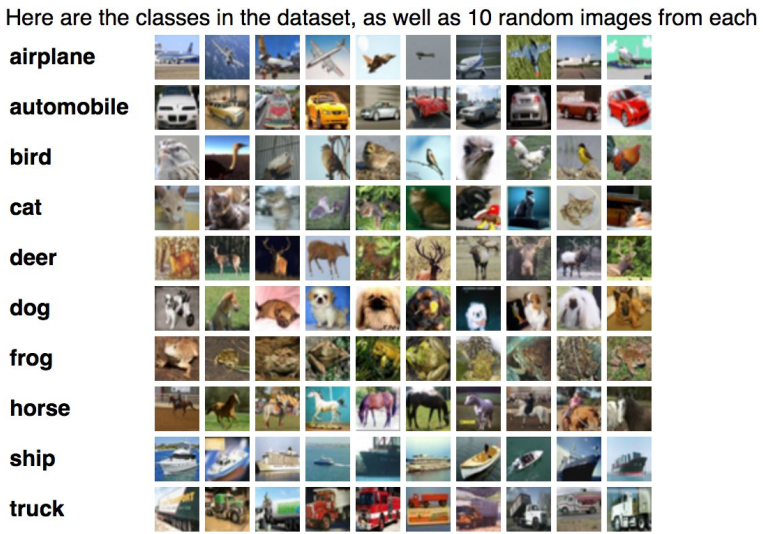
0 Accuracy: 0.9933
1 Accuracy: 0.9946
2 Accuracy: 0.9934
3 Accuracy: 0.9935
4 Accuracy: 0.9935
5 Accuracy: 0.9949
6 Accuracy: 0.9941

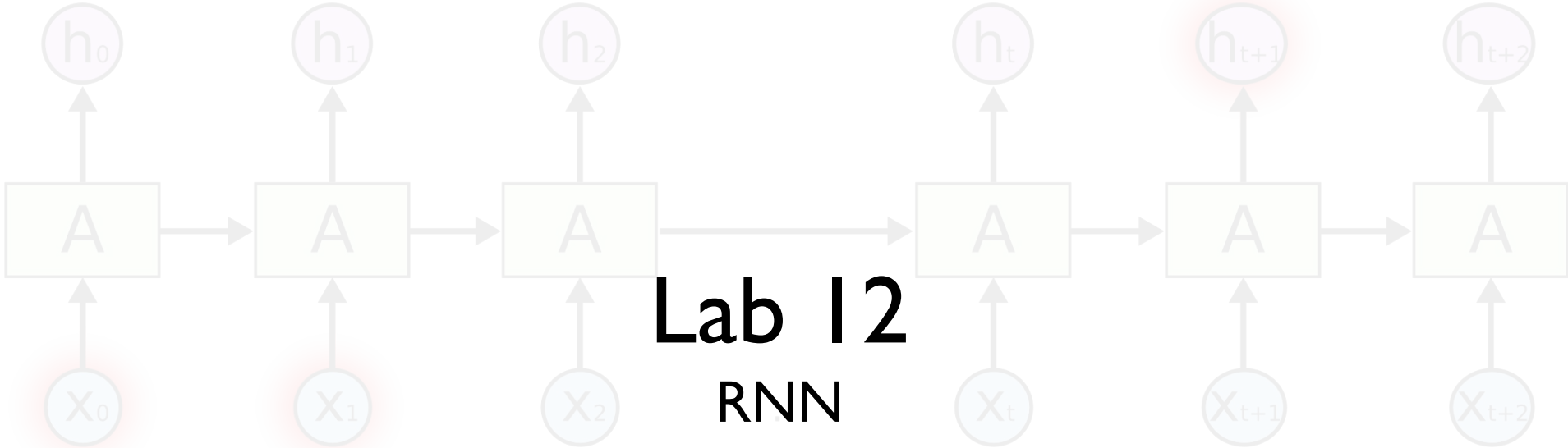
Ensemble accuracy: **0.9952**

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-11-5-mnist_cnn_ensemble_layers.py

Exercise

- Deep & Wide?
- CIFAR 10
- ImageNet





Lab 12
RNN

Sung Kim <hunkim+ml@gmail.com>
http://hunkim.github.io/ml/