class18_neural_networks

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1 Data Mining:Statistical Modeling and Learning from Data

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1.1.1 Exercises - Neural Networks

Basic Operations example using TensorFlow library.

`conda install tensorflow keras`

or

`pip install tensorflow keras`

```
In [1]: %pylab inline

        import tensorflow as tf
```

```
Populating the interactive namespace from numpy and matplotlib
```

We are also going to use pydot to show computation graphs.

`conda install pydot graphviz`

```
In [2]: import pydot
        from itertools import chain
        def tf_graph_to_dot(in_graph):
            dot = pydot.Dot()
            dot.set('rankdir', 'LR')
            dot.set('concentrate', True)
            dot.set_node_defaults(shape='record')
            all_ops = in_graph.get_operations()
            all_tens_dict = {k: i for i,k in enumerate(set(chain(*[c_op.outputs for c_op in all_
            for c_node in all_tens_dict.keys():
                node = pydot.Node(c_node.name)#, label=label)
                dot.add_node(node)
            for c_op in all_ops:
                for c_output in c_op.outputs:
```

```
                for c_input in c_op.inputs:
                    dot.add_edge(pydot.Edge(c_input.name, c_output.name))
        return dot

    from IPython.display import SVG
    def show_graph(graph):
        tf_graph_to_dot(graph).write_svg('simple_tf.svg')
        return SVG('simple_tf.svg')
```

1.1.2 Basic constant operations

The value returned by the constructor represents the output of the Constant op.

```
In [3]: a = tf.constant(2, name='a')
        b = tf.constant(3, name='b')
```

```
In [4]: c = a+b
```

```
In [5]: d = c**2
```

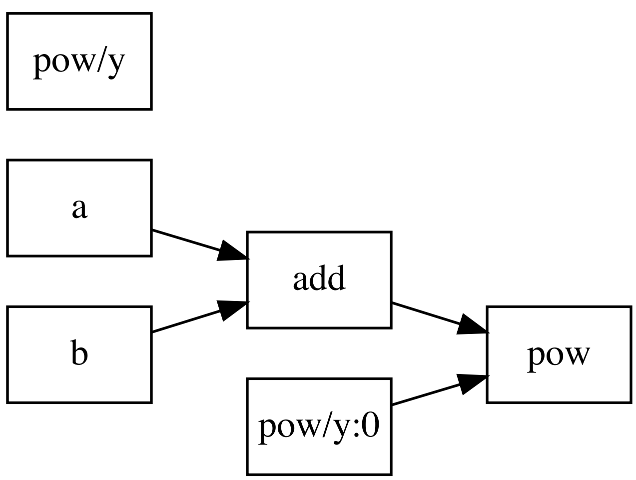
```
In [6]: d
```

```
Out[6]: <tf.Tensor 'pow:0' shape=() dtype=int32>
```

The variable `d` is a `Tensor`, i.e. a result of a computation graph.

```
In [7]: show_graph(tf.get_default_graph())
```

```
Out[7]:
```



Launch the default graph.

In [8]:
```
with tf.Session() as sess:
    print "a: %i" % sess.run(a), "b: %i" % sess.run(b)
    print "Addition with constants: %i" % sess.run(a+b)
    print "Multiplication with constants: %i" % sess.run(a*b)
```

```
a: 2 b: 3
Addition with constants: 5
Multiplication with constants: 6
```

In [9]:
```
tf.reset_default_graph()
```

1.1.3 Basic Operations with variable as graph input

The value returned by the constructor represents the output of the Variable op. (define as input when running session) tf Graph input

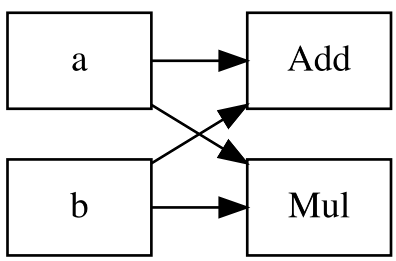
In [10]:
```
a = tf.placeholder(tf.int16, name='a')
b = tf.placeholder(tf.int16, name='b')
```

Define some operations

In [11]:
```
add = tf.add(a, b)
mul = tf.multiply(a, b)
```

In [12]:
```
show_graph(tf.get_default_graph())
```

Out[12]:



Launch the default graph.

In [13]:
```
with tf.Session() as sess:
    # Run every operation with variable input
    print "Addition with variables: %i" % sess.run(add, feed_dict={a: 2, b: 4})
    print "Multiplication with variables: %i" % sess.run(mul, feed_dict={a: 2, b: 3})
```

```
Addition with variables: 6
Multiplication with variables: 6
```

In [14]:
```
tf.reset_default_graph()
```

1.1.4 Matrix Multiplication

Create a Constant op that produces a 1x2 matrix. The op is added as a node to the default graph. The value returned by the constructor represents the output of the Constant op.

```
In [15]: matrix1 = tf.constant([[3., 3.]], name='input1')
```

```
In [16]: matrix1
```

```
Out[16]: <tf.Tensor 'input1:0' shape=(1, 2) dtype=float32>
```

Create another Constant that produces a 2x1 matrix.

```
In [17]: matrix2 = tf.constant([[2.],[2.]], name='input2')
```

```
In [18]: matrix2
```

```
Out[18]: <tf.Tensor 'input2:0' shape=(2, 1) dtype=float32>
```

Create a Matmul op that takes 'matrix1' and 'matrix2' as inputs.
The returned value, 'product', represents the result of the matrix multiplication.

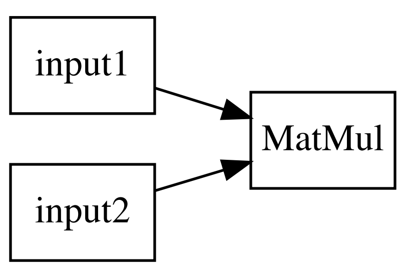
```
In [19]: product = tf.matmul(matrix1, matrix2)
```

```
In [20]: product
```

```
Out[20]: <tf.Tensor 'MatMul:0' shape=(1, 1) dtype=float32>
```

```
In [21]: show_graph(tf.get_default_graph())
```

```
Out[21]:
```



To run the matmul op we call the session 'run()' method, passing 'product' which represents the output of the matmul op. This indicates to the call that we want to get the output of the matmul op back.

All inputs needed by the op are run automatically by the session. They typically are run in parallel.

The call 'run(product)' thus causes the execution of threes ops in the graph: the two constants and matmul.

The output of the op is returned in 'result' as a numpy `ndarray` object.

In [22]:
```
with tf.Session() as sess:
    result = sess.run(product)
    print result
```

```
[[ 12.]]
```

In [23]:
```
tf.reset_default_graph()
```

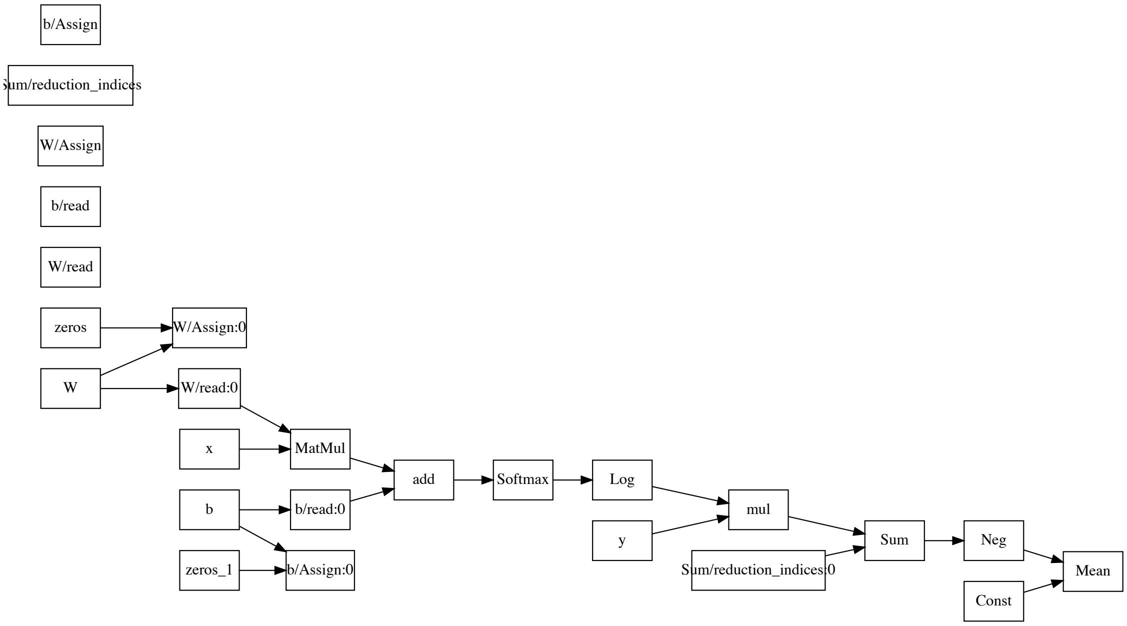
1.2 Logistic regression

This example is using the MNIST database of handwritten digits (http://yann.lecun.com/exdb/mnist/)

In [24]:
```
# tf Graph Input
x = tf.placeholder(tf.float32, [None, 784], name='x') # mnist data image of shape 28*28
y = tf.placeholder(tf.float32, [None, 10], name='y') # 0-9 digits recognition => 10 cla

# Set model weights
W = tf.Variable(tf.zeros([784, 10]), name='W')
b = tf.Variable(tf.zeros([10]), name='b')

# Construct model
pred = tf.nn.softmax(tf.matmul(x, W) + b) # Softmax

# Minimize error using cross entropy
cost = tf.reduce_mean(-tf.reduce_sum(y*tf.log(pred), reduction_indices=1))
```

In [25]:
```
show_graph(tf.get_default_graph())
```

Out[25]:



Calculate the gradients of `W` and `b` with respect to `cost`

```
In [26]: W_grads, b_grads = tf.gradients(cost, [W, b])
         W_grads, b_grads
```

```
Out[26]: (<tf.Tensor 'gradients/MatMul_grad/MatMul_1:0' shape=(784, 10) dtype=float32>,
          <tf.Tensor 'gradients/add_grad/Reshape_1:0' shape=(10,) dtype=float32>)
```

```
In [27]: from tensorflow.examples.tutorials.mnist import input_data
         mnist = input_data.read_data_sets("MNIST_data/", one_hot=True)
```

```
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 [28]: # Initializing the variables
         init = tf.global_variables_initializer()
```

```
In [29]: mnist.train.labels[:10]
```

```
Out[29]: array([[ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  1.,  0.,  0.],
                [ 0.,  0.,  0.,  1.,  0.,  0.,  0.,  0.,  0.,  0.],
                [ 0.,  0.,  0.,  0.,  1.,  0.,  0.,  0.,  0.,  0.],
                [ 0.,  0.,  0.,  0.,  0.,  0.,  1.,  0.,  0.,  0.],
                [ 0.,  1.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.],
                [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  1.,  0.],
                [ 0.,  1.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.],
                [ 1.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.],
                [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  1.],
                [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  1.,  0.]])
```

```
In [30]: x_input = mnist.train.images[:10]
         y_input = mnist.train.labels[:10]

         print 'y_input:\n', y_input

         with tf.Session() as sess:
             sess.run(init)
             v_pred = sess.run(pred, feed_dict={x: x_input, y: y_input})
             print 'v_pred:\n', v_pred
             v_cost = sess.run(cost, feed_dict={x: x_input, y: y_input})
             print 'v_cost:\n', v_cost
             v_W_grads = sess.run(W_grads, feed_dict={x: x_input, y: y_input})
             v_b_grads = sess.run(b_grads, feed_dict={x: x_input, y: y_input})
```

```
y_input:
[[ 0.  0.  0.  0.  0.  0.  0.  1.  0.  0.]
 [ 0.  0.  0.  1.  0.  0.  0.  0.  0.  0.]
 [ 0.  0.  0.  0.  1.  0.  0.  0.  0.  0.]
 [ 0.  0.  0.  0.  0.  0.  1.  0.  0.  0.]
 [ 0.  1.  0.  0.  0.  0.  0.  0.  0.  0.]
 [ 0.  0.  0.  0.  0.  0.  0.  0.  1.  0.]
 [ 0.  1.  0.  0.  0.  0.  0.  0.  0.  0.]
 [ 1.  0.  0.  0.  0.  0.  0.  0.  0.  0.]
 [ 0.  0.  0.  0.  0.  0.  0.  0.  0.  1.]
 [ 0.  0.  0.  0.  0.  0.  0.  0.  1.  0.]]
v_pred:
[[ 0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1]
 [ 0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1]
 [ 0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1]
 [ 0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1]
 [ 0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1]
 [ 0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1]
 [ 0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1]
 [ 0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1]
 [ 0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1]
 [ 0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1]]
v_cost:
2.30259
```

```
In [31]: # tf.reduce_mean(-tf.reduce_sum(y*tf.log(pred), reduction_indices=1))
         print np.mean(-np.sum(y_input*np.log(v_pred), axis=1))
```

```
2.30258512497
```

```
In [32]: print v_b_grads
```

```
[  1.30385160e-08  -1.00000001e-01   1.00000001e-01   9.31322575e-09
   1.67638063e-08   1.00000001e-01   1.30385160e-08   9.31322575e-09
  -9.99999866e-02   1.02445483e-08]
```

Create a Gradient Descent Optimizer

```
In [33]: learning_rate = 0.01

         # Gradient Descent
         optimizer = tf.train.GradientDescentOptimizer(learning_rate).minimize(cost)
```

```
In [34]: # Parameters
         training_epochs = 25
         batch_size = 100
```

```
display_step = 1

total_batch = int(mnist.train.num_examples/batch_size)
print total_batch
```

```
550
```

Launch the graph

```
In [35]: with tf.Session() as sess:
             sess.run(init)

             # Training cycle
             for epoch in range(training_epochs):
                 avg_cost = 0.
                 # Loop over all batches
                 for i in range(total_batch):
                     batch_xs, batch_ys = mnist.train.next_batch(batch_size)
                     # Fit training using batch data
                     _, c = sess.run([optimizer, cost], feed_dict={x: batch_xs,
                                                                   y: batch_ys})
                     # Compute average loss
                     avg_cost += c / total_batch
                 # Display logs per epoch step
                 if (epoch+1) % display_step == 0:
                     print "Epoch:", '%04d' % (epoch+1), "cost=", "{:.9f}".format(avg_cost)

             print "Optimization Finished!"

             # Test model
             correct_prediction = tf.equal(tf.argmax(pred, 1), tf.argmax(y, 1))
             # Calculate accuracy for 3000 examples
             accuracy = tf.reduce_mean(tf.cast(correct_prediction, tf.float32))
             print "Accuracy:", accuracy.eval({x: mnist.test.images[:3000], y: mnist.test.labels
```

```
Epoch: 0001 cost= 1.183154716
Epoch: 0002 cost= 0.665118501
Epoch: 0003 cost= 0.552713217
Epoch: 0004 cost= 0.498661404
Epoch: 0005 cost= 0.465491770
Epoch: 0006 cost= 0.442607325
Epoch: 0007 cost= 0.425527330
Epoch: 0008 cost= 0.412178677
Epoch: 0009 cost= 0.401393159
Epoch: 0010 cost= 0.392407267
Epoch: 0011 cost= 0.384750850
Epoch: 0012 cost= 0.378167388
Epoch: 0013 cost= 0.372413613
```

```
Epoch: 0014 cost= 0.367275904
Epoch: 0015 cost= 0.362740646
Epoch: 0016 cost= 0.358594548
Epoch: 0017 cost= 0.354908445
Epoch: 0018 cost= 0.351491049
Epoch: 0019 cost= 0.348323269
Epoch: 0020 cost= 0.345414642
Epoch: 0021 cost= 0.342751602
Epoch: 0022 cost= 0.340224722
Epoch: 0023 cost= 0.337912710
Epoch: 0024 cost= 0.335758742
Epoch: 0025 cost= 0.333729535
Optimization Finished!
Accuracy: 0.888667
```

In [48]:
```
tf.reset_default_graph()
```

1.3 Convolutional Network

In [49]:
```
# Parameters
learning_rate = 0.001
training_iters = 200000
batch_size = 128
display_step = 10

# Network Parameters
n_input = 784 # MNIST data input (img shape: 28*28)
n_classes = 10 # MNIST total classes (0-9 digits)
dropout = 0.75 # Dropout, probability to keep units

# tf Graph input
x = tf.placeholder(tf.float32, [None, n_input])
y = tf.placeholder(tf.float32, [None, n_classes])
keep_prob = tf.placeholder(tf.float32) # dropout (keep probability)
```

In [50]:
```
# Create some wrappers for simplicity
def conv2d(x, W, b, strides=1):
    # Conv2D wrapper, with bias and relu activation
    x = tf.nn.conv2d(x, W, strides=[1, strides, strides, 1], padding='SAME')
    x = tf.nn.bias_add(x, b)
    return tf.nn.relu(x)


def maxpool2d(x, k=2):
    # MaxPool2D wrapper
    return tf.nn.max_pool(x, ksize=[1, k, k, 1], strides=[1, k, k, 1],
                          padding='SAME')
```

```
# Create model
def conv_net(x, weights, biases, dropout):
    # Reshape input picture
    x = tf.reshape(x, shape=[-1, 28, 28, 1])

    # Convolution Layer
    conv1 = conv2d(x, weights['wc1'], biases['bc1'])
    # Max Pooling (down-sampling)
    conv1 = maxpool2d(conv1, k=2)

    # Convolution Layer
    conv2 = conv2d(conv1, weights['wc2'], biases['bc2'])
    # Max Pooling (down-sampling)
    conv2 = maxpool2d(conv2, k=2)

    # Fully connected layer
    # Reshape conv2 output to fit fully connected layer input
    fc1 = tf.reshape(conv2, [-1, weights['wd1'].get_shape().as_list()[0]])
    fc1 = tf.add(tf.matmul(fc1, weights['wd1']), biases['bd1'])
    fc1 = tf.nn.relu(fc1)
    # Apply Dropout
    fc1 = tf.nn.dropout(fc1, dropout)

    # Output, class prediction
    out = tf.add(tf.matmul(fc1, weights['out']), biases['out'])
    return out
```

In [51]:
```
# Store layers weight & bias
weights = {
    # 5x5 conv, 1 input, 32 outputs
    'wc1': tf.Variable(tf.random_normal([5, 5, 1, 32])),
    # 5x5 conv, 32 inputs, 64 outputs
    'wc2': tf.Variable(tf.random_normal([5, 5, 32, 64])),
    # fully connected, 7*7*64 inputs, 1024 outputs
    'wd1': tf.Variable(tf.random_normal([7*7*64, 1024])),
    # 1024 inputs, 10 outputs (class prediction)
    'out': tf.Variable(tf.random_normal([1024, n_classes]))
}

biases = {
    'bc1': tf.Variable(tf.random_normal([32])),
    'bc2': tf.Variable(tf.random_normal([64])),
    'bd1': tf.Variable(tf.random_normal([1024])),
    'out': tf.Variable(tf.random_normal([n_classes]))
}
```

```
    # Construct model
    pred = conv_net(x, weights, biases, keep_prob)

    # Define loss and optimizer
    cost = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(logits=pred, labels=y))
    optimizer = tf.train.AdamOptimizer(learning_rate=learning_rate).minimize(cost)

    # Evaluate model
    correct_pred = tf.equal(tf.argmax(pred, 1), tf.argmax(y, 1))
    accuracy = tf.reduce_mean(tf.cast(correct_pred, tf.float32))

    # Initializing the variables
    init = tf.global_variables_initializer()
```

In [ ]:
```
show_graph(tf.get_default_graph())
```

In [ ]:
```
# Launch the graph
with tf.Session() as sess:
    sess.run(init)
    step = 1
    # Keep training until reach max iterations
    while step * batch_size < training_iters:
        batch_x, batch_y = mnist.train.next_batch(batch_size)
        # Run optimization op (backprop)
        sess.run(optimizer, feed_dict={x: batch_x, y: batch_y,
                                       keep_prob: dropout})
        if step % display_step == 0:
            # Calculate batch loss and accuracy
            loss, acc = sess.run([cost, accuracy], feed_dict={x: batch_x,
                                                              y: batch_y,
                                                              keep_prob: 1.})
            print "Iter " + str(step*batch_size) + ", Minibatch Loss= " + \
                  "{:.6f}".format(loss) + ", Training Accuracy= " + \
                  "{:.5f}".format(acc)
        step += 1
    print "Optimization Finished!"

    # Calculate accuracy for 256 mnist test images
    print "Testing Accuracy:", \
        sess.run(accuracy, feed_dict={x: mnist.test.images[:256],
                                      y: mnist.test.labels[:256],
                                      keep_prob: 1.})
```

Exercise: Test the model with other optimization algorithms: - tf.train.MomentumOptimizer - tf.train.AdagradOptimizer - tf.train.AdamOptimizer

(Reference: http://sebastianruder.com/optimizing-gradient-descent/)

1.4 Convolutional Network with Keras

```
In [54]: from keras.models import Sequential
         from keras.layers import Dense
         from keras.layers import Dropout
         from keras.utils import np_utils
```

```
Using TensorFlow backend.
```

```
In [55]: X_train, Y_train = mnist.train.images, mnist.train.labels
         X_test, Y_test = mnist.test.images, mnist.test.labels
```

```
In [56]: n_input = 784 # MNIST data input (img shape: 28*28)
         n_classes = 10 # MNIST total classes (0-9 digits)
```

1.4.1 Baseline model

```
In [57]: # define baseline model
         def baseline_model():
             # create model
             model = Sequential()
             model.add(Dense(n_input, input_dim=n_input, kernel_initializer='normal', activation
             model.add(Dense(n_classes, kernel_initializer='normal', activation='softmax'))
             # Compile model
             model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy
             return model
```

Reference for Keras optimization algorithms:
https://keras.io/optimizers/

```
In [ ]: # build the model
        model = baseline_model()
        # Fit the model
        model.fit(X_train, Y_train, validation_data=(X_test, Y_test), epochs=10, batch_size=200,
        # Final evaluation of the model

        scores = model.evaluate(X_test, Y_test, verbose=0)
        print("Baseline Error: %.2f%%" % (100-scores[1]*100))
```

1.4.2 Larger model

```
In [58]: from keras.models import Sequential
         from keras.layers import Dense, Dropout, Flatten
         from keras.layers.convolutional import Convolution2D, MaxPooling2D
         from keras import backend as K
         K.set_image_dim_ordering('th')
```

```
In [59]: def larger_model():
             # create model
```

```
    model = Sequential()
    model.add(Convolution2D(30, (5, 5), padding='valid', input_shape=(1, 28, 28), activ
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Convolution2D(15, (3, 3), activation='relu'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Dropout(0.2))
    model.add(Flatten())
    model.add(Dense(128, activation='relu'))
    model.add(Dense(50, activation='relu'))
    model.add(Dense(n_classes, activation='softmax'))
    # Compile model
    model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy
    return model
```

```
In [ ]: # build the model
        model = larger_model()
        # Fit the model
        model.fit(X_train.reshape(-1, 1, 28, 28), Y_train,
                  validation_data=(X_test.reshape(-1, 1, 28, 28), Y_test),
                  nb_epoch=10, batch_size=200, verbose=2)
        # Final evaluation of the model
        scores = model.evaluate(X_test.reshape(-1, 1, 28, 28), Y_test, verbose=0)
        print("Baseline Error: %.2f%%" % (100-scores[1]*100))
```

2 Inception V3 model

Implementation of Google Inception V3 model for Keras.

References - Rethinking the Inception Architecture for Computer Vision - Google Research Blog

Credits: François Chollet (https://github.com/fchollet/deep-learning-models)

```
In [60]: from keras.applications import inception_v3
         from keras.preprocessing import image
```

```
In [61]: img_path = 'kitten.png'
         img = image.load_img(img_path, target_size=(299, 299))
         x = image.img_to_array(img)
         x = np.expand_dims(x, axis=0)

         x = inception_v3.preprocess_input(x)
```

```
In [62]: img
```

```
Out[62]:
```

```
In [63]: model = inception_v3.InceptionV3(include_top=True, weights='imagenet')
```

```
/Users/panisson/anaconda2/lib/python2.7/site-packages/keras/applications/inception_v3.py:366: Us
  warnings.warn('You are using the TensorFlow backend, yet you '
```

```
In [64]: preds = model.predict(x)
         print('Predicted:', inception_v3.decode_predictions(preds))
```

```
('Predicted:', [[(u'n02123159', u'tiger_cat', 0.46220145), (u'n02124075', u'Egyptian_cat', 0.132
```