linear_regression

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1 Learn Tensorflow via a linear regression model

In this excercise, you will learn tensorflow in steps. Please use python 3 and tensorflow >=1.4.0.

```
In [1]: # A bit of setup

        import numpy as np
        import tensorflow as tf
        import matplotlib.pyplot as plt

        from implementations.a_tensorflow import regression_graph
        from plot_graph import show_graph


        %matplotlib inline
        plt.rcParams['figure.figsize'] = (10.0, 8.0) # set default size of plots
        plt.rcParams['image.interpolation'] = 'nearest'
        plt.rcParams['image.cmap'] = 'gray'

        # for auto-reloading external modules
        # see http://stackoverflow.com/questions/1907993/autoreload-of-modules-in-ipython
        %load_ext autoreload
        %autoreload 2
```

1.1 Tensorflow graph

In the first step, we test a tensorflow graph with all constants. Please read `a_tensorflow.regression_graph()`. It calculates the squared loss for the linear regression model.

1.1.1 Question 1 (4 points):

Please run the code in the cell below, comment out the first line, and then run the cell multiple times. Why does the right-most graph get numbers on it nodes with your runs?

1.1.2 Answer:

This is because we comment out the first line so we don't reset the graph. Therefore, everytime we initialize a regression_graph object, we actually create a new regression graph in addition to the existing graph. These objects are numbered 1, 2, 3, 4, ...

```
In [2]: #tf.reset_default_graph()
        loss = regression_graph() # the first function in a_tensorflow
        show_graph(loss.graph)
```

```
<IPython.core.display.HTML object>
```

Note 1: use `tf.Session()` to run the graph and evaluate the value of a graph node. Note 2: retrieve a graph node by its name.

1.1.3 Question 2 (4 points):

Please uncomment the last two lines and evaluate the loss.

```
In [4]: tf.reset_default_graph()
        loss = regression_graph(print_info=True)
        session = tf.Session()

        # retrieve the variable from the graph
        f = tf.get_default_graph().get_tensor_by_name('score:0')
        print("We retrieve f from the graph and show its value: ", session.run(f))

        print('The loss is ')
        session.run(loss)
```

```
Msg from the function: we can evaluate any value in the graph with tf.Session
Msg from the function: the value of f = w * x + b is 2.18
We retrieve f from the graph and show its value:  2.18
The loss is
```

```
Out[4]: 3.9204001
```

1.2 Tensorflow graph with vectors

We can get a tensor's shape with its member function `get_shape()`. Note that this function is python function, not a tensorflow operation, so it runs when you build the graph.

We can also use the tensorflow operation `tf.shape()` to get the shape of a tensor. Since it is an operation, it is part of the graph. You need to run the operation to get the actual value.

1.2.1 Question 3 (4 points):

Complete the code in the function `regression_graph_vectorized` so the following cell can run.

```
In [8]: from implementations.a_tensorflow import regression_graph_vectorized
        tf.reset_default_graph()
        loss = regression_graph_vectorized(print_info=True)

        print(tf.Session().run(loss))
```

```
By w.get_shape(), we get the shape of the tensor w: (2,)
With tf.shape(w), we get the shape of w as a one-element tensor: Tensor("Shape:0", shape=(1,), d
The shape of tf.matmul(x, w) is: (3, 1)
The shape of tf.squeeze(tf.matmul(x, w)) is: (3,)
35.343597
```

1.3 Place holder in Tensorflow graph

A `placeholder` holds space for the data that will be fed into the graph in the future. It can has shape `None` in one or more dimensions. The size of that dimension will be decided by the data.

1.3.1 Question 4 (4 points):

Please implement the function `regression_graph_with_placeholder` and get the cell below run.

```
In [14]: from implementations.a_tensorflow import regression_graph_with_placeholder
         tf.reset_default_graph()

         # build a graph with place holders
         x = tf.placeholder(shape=[None, 2], dtype=tf.float32, name='feature')
         y = tf.placeholder(shape=[None], dtype=tf.float32, name='label')

         print('The place holder x is:', x) # take a look of the place holder

         loss = regression_graph_with_placeholder(x=x, y=y)

         # need to feed in actual values to x and y to evaluate the variable loss

         # numpy values
         np.random.seed(seed=2019)
         npx = np.random.random_sample([10, 2])
         npy = np.squeeze(npx.dot([[0.3], [0.6]])) + 1.0 + 0.05 * np.random.random_sample([10])

         # this line cannot run because you need to feed in values for place holders. Can you fi
         # tf.Session().run(loss)
         l1 = tf.Session().run(loss, feed_dict={x: npx, y: npy})
         print("Loss 1 = ", l1)
```

```
        # feed in a different set of data
        npx = np.random.random_sample([10, 2])
        npy = np.squeeze(npx.dot([[0.7], [0.9]])) + 1.0 + 0.05 * np.random.random_sample([10])

        # it get a different loss value
        l2 = tf.Session().run(loss, feed_dict={x: npx, y: npy})
        print("Loss 2 = ", l2)
```

```
The place holder x is: Tensor("feature:0", shape=(?, 2), dtype=float32)
Loss 1 =  14.350067
Loss 2 =  8.833251
```

1.4 Tensorflow graph with variables

We need to use `tf.Variable` to declare variables that we can optimize later. We often use `Variables` for model parameters, which are mutable. We seldomly use `Variables` for data.

1.4.1 Question 5 (4 points):

Please implement the function `regression_graph_with_variable` and get the cell below run.

```
In [16]: from implementations.a_tensorflow import regression_graph_with_variable
         tf.reset_default_graph()

         w = tf.Variable(np.full(shape=[2], fill_value=1.6, dtype=np.float32), name='weight')
         b = tf.Variable(tf.constant(0.9), name='bias')

         loss = regression_graph_with_variable(w=w, b=b)


         session = tf.Session()

         init = tf.global_variables_initializer() # Need to initialize the variables
         session.run(init)

         session.run(loss) # you cannot directly run loss because you need to initialize variabl
```

```
Out[16]: 35.343597
```

1.5 Gradient calculation

Tensorflow can calculate gradient with respect to a `Variable` (but not a `constant` or a `placeholder`). Let's use an optimizer to optimize a gradient.

1.5.1 Question 6 (4 points):

Please read the documentation of `compute_gradients` and `apply_gradients`. Can you update w and b ten times and make the loss smaller?

```
In [20]: # initialize an optimizer
         opt = tf.train.GradientDescentOptimizer(learning_rate=0.01)
         grads_vars = opt.compute_gradients(loss, var_list=[w, b])
         update = opt.apply_gradients(grads_vars)


         print('The current loss is: ', session.run(loss))
         print('The current variable gradients and values are')
         print(session.run(grads_vars))

         for iter in range(10):  # can you run multiple steps to minimize the loss?
             session.run(update)

             print('The current loss is: ', session.run(loss))
         #     print('The current variable gradients and values are')
         #     print(session.run(grads_vars)) # This returns an array corresponding to the gradi
```

```
The current loss is:  0.077929914
The current variable gradients and values are
[(array([ 0.13101178, -0.03523043], dtype=float32), array([1.1932504, 0.8393767], dtype=float32)
The current loss is:  0.07761953
The current loss is:  0.07736203
The current loss is:  0.07713561
The current loss is:  0.07692779
The current loss is:  0.076731496
The current loss is:  0.07654259
The current loss is:  0.07635878
The current loss is:  0.07617866
The current loss is:  0.07600151
The current loss is:  0.07582683
```

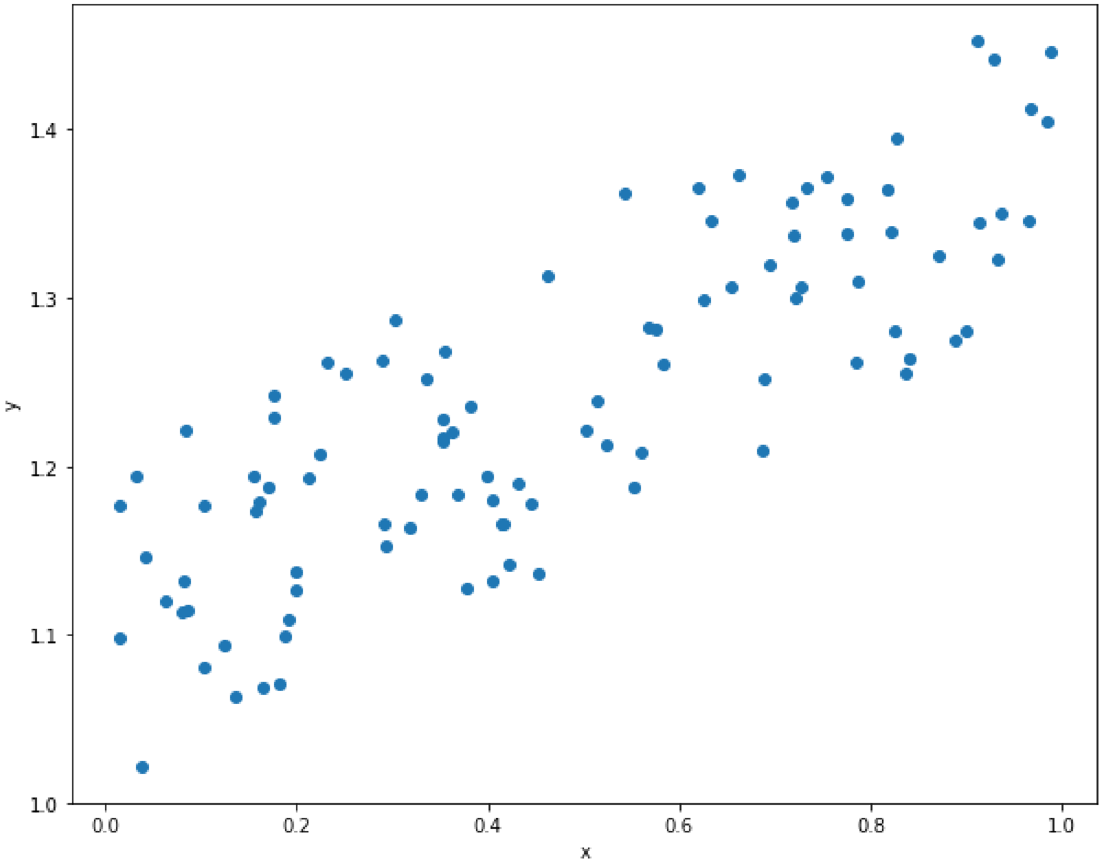
1.6 Compose the full version of linear regression

1.6.1 Question 7 (4 points):

Can you use all techniques you have learned above to compose a full version of linear regression?

We use data with one feature only so we can plot the data easily. Assume the feature matrix is npx and the label is npy.

```
In [37]: # plot the data before fitting the model.
         # numpy values
         N = 100
         npx = np.random.random_sample([N, 1])
         npy = np.squeeze(npx.dot([[0.3]])) + 1.0 + 0.2 * np.random.random_sample([N])

         plt.plot(npx, npy, 'o')
         plt.ylabel('y')
         plt.xlabel('x')
         plt.show()
```

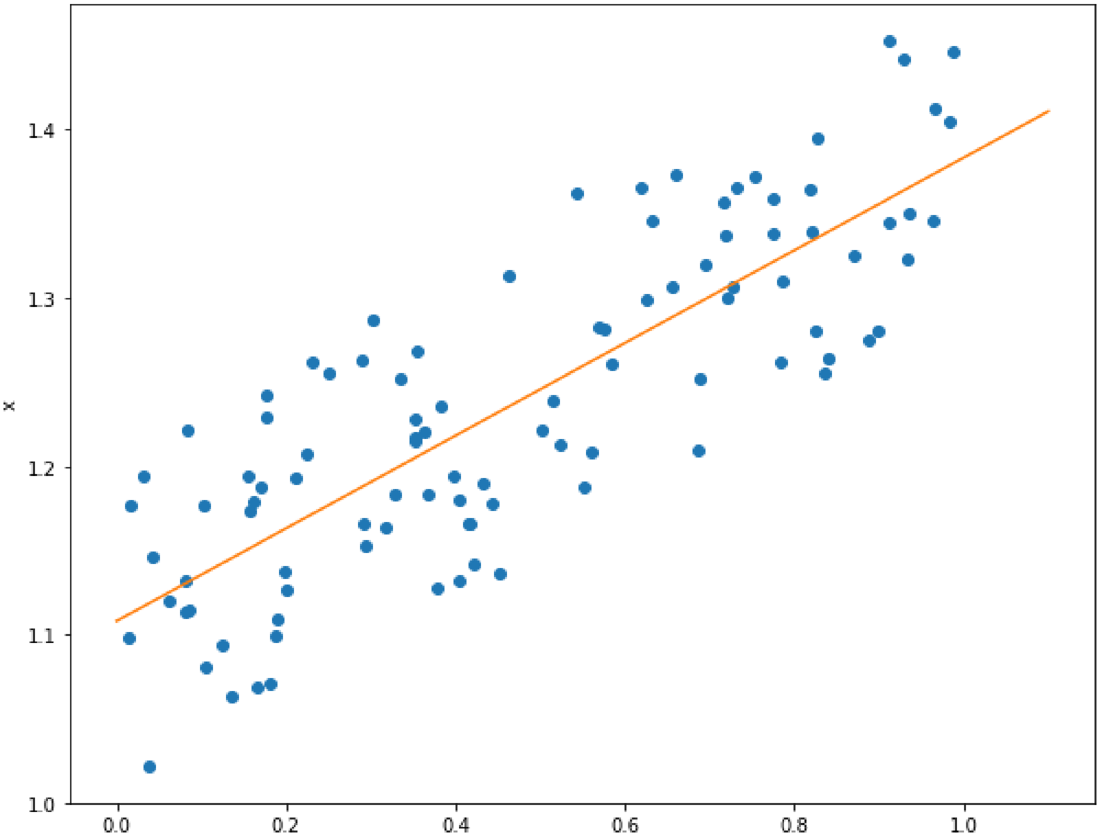


```
In [42]: from implementations.a_tensorflow import regression_graph_full
         tf.reset_default_graph()

         x = tf.placeholder(shape=[None,1], dtype=tf.float32, name='feature')
         y = tf.placeholder(shape=[None], dtype=tf.float32, name='label')

         w = tf.Variable(np.full(shape=[1], fill_value=1.6, dtype=np.float32), name='weight')
         b = tf.Variable(tf.constant(0.9), name='bias')

         loss = regression_graph_full(x=x, y=y, w=w, b=b) # you need to implement this function

         # get an optimizer
         opt = tf.train.GradientDescentOptimizer(learning_rate=0.001)
         # calculate the gradient with compute_gradients
         grads_vars = opt.compute_gradients(loss, var_list=[w, b])
         # get an update operation with apply_gradients
         update = opt.apply_gradients(grads_vars)
```

```
# get a session
session = tf.Session()

# initialize your variables, namely w and b
init = tf.global_variables_initializer() # Need to initialize the variables
session.run(init)

# get feeding dictionary
# npx = np.expand_dims(npx, axis=1)
# npy = np.expand_dims(npy, axis=1)

feed_dict={x: npx, y: npy}

print('The current loss is: ', session.run(loss, feed_dict=feed_dict))
print('The current variable gradients and values are')
print(session.run(grads_vars, feed_dict=feed_dict)) # something is missing here?
print(session.run(w))
print(session.run(b))

session.run(update, feed_dict=feed_dict)

for iter in range(1000):  # Run 1000 steps to minimize the loss
    # perform gradient steps by running the update operation
    session.run(update, feed_dict=feed_dict)

    if iter % 100 == 1:
        print('Loss values become: ', session.run(loss, feed_dict=feed_dict))
    session.run(grads_vars, feed_dict=feed_dict)


# obtain the trained model
npw = session.run(w)
npb = session.run(b)
```

```
The current loss is:  32.231148
The current variable gradients and values are
[(array([61.301514], dtype=float32), array([1.6], dtype=float32)), (83.37443, 0.9)]
[1.6]
0.9
Loss values become:  14.168369
Loss values become:  0.9784701
Loss values become:  0.3453107
Loss values become:  0.30256417
Loss values become:  0.29967827
Loss values become:  0.29948324
Loss values become:  0.29947016
Loss values become:  0.29946935
Loss values become:  0.29946917
Loss values become:  0.29946917
```

```
In [43]: # Plot the result

         x_line = np.arange(12) / 10.0
         y_line = x_line * np.squeeze(npw) + npb

         plt.plot(npx, npy, 'o')
         plt.plot(x_line, y_line)
         plt.ylabel('y')
         plt.ylabel('x')
         plt.show()
```



```
In [ ]:
```