

# C2\_W2\_Lab\_1\_training-basics

February 10, 2021

## 1 Custom Training Basics

In this ungraded lab you'll gain a basic understanding of building custom training loops. - It takes you through the underlying logic of fitting any model to a set of inputs and outputs. - You will be training your model on the linear equation for a straight line,  $wx + b$ . - You will implement basic linear regression from scratch using gradient tape. - You will try to minimize the loss incurred by the model using linear regression.

### 1.1 Imports

```
[1]: from __future__ import absolute_import, division, print_function, \
      ↪ unicode_literals

try:
    # %tensorflow_version only exists in Colab.
    %tensorflow_version 2.x
except Exception:
    pass

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

### 1.2 Define Model

You define your model as a class. -  $\mathbf{x}$  is your input tensor. - The model should output values of  $\mathbf{wx+b}$ . - You'll start off by initializing  $w$  and  $b$  to random values. - During the training process, values of  $w$  and  $b$  get updated in accordance with linear regression so as to minimize the loss incurred by the model. - Once you arrive at optimal values for  $w$  and  $b$ , the model would have been trained to correctly predict the values of  $wx+b$ .

Hence, -  $\mathbf{w}$  and  $\mathbf{b}$  are trainable weights of the model. -  $\mathbf{x}$  is the input -  $\mathbf{y} = wx + b$  is the output

```
[2]: class Model(object):
      def __init__(self):
```

```

    # Initialize the weights to `2.0` and the bias to `1.0`
    # In practice, these should be initialized to random values (for example,
    ↪with `tf.random.normal`)
    self.w = tf.Variable(2.0)
    self.b = tf.Variable(1.0)

    def __call__(self, x):
        return self.w * x + self.b

model = Model()

```

### 1.2.1 Define a loss function

A loss function measures how well the output of a model for a given input matches the target output. - The goal is to minimize this difference during training. - Let's use the standard L2 loss, also known as the least square errors

$$Loss = \sum_i (y_{pred}^i - y_{target}^i)^2$$

```

[3]: def loss(predicted_y, target_y):
      return tf.reduce_mean(tf.square(predicted_y - target_y))

```

### 1.2.2 Obtain training data

First, synthesize the training data using the “true” w and “true” b.

$$y = w_{true} \times x + b_{true}$$

```

[4]: TRUE_w = 3.0
      TRUE_b = 2.0
      NUM_EXAMPLES = 1000

      xs = tf.random.normal(shape=[NUM_EXAMPLES])

      ys = (TRUE_w * xs) + TRUE_b

```

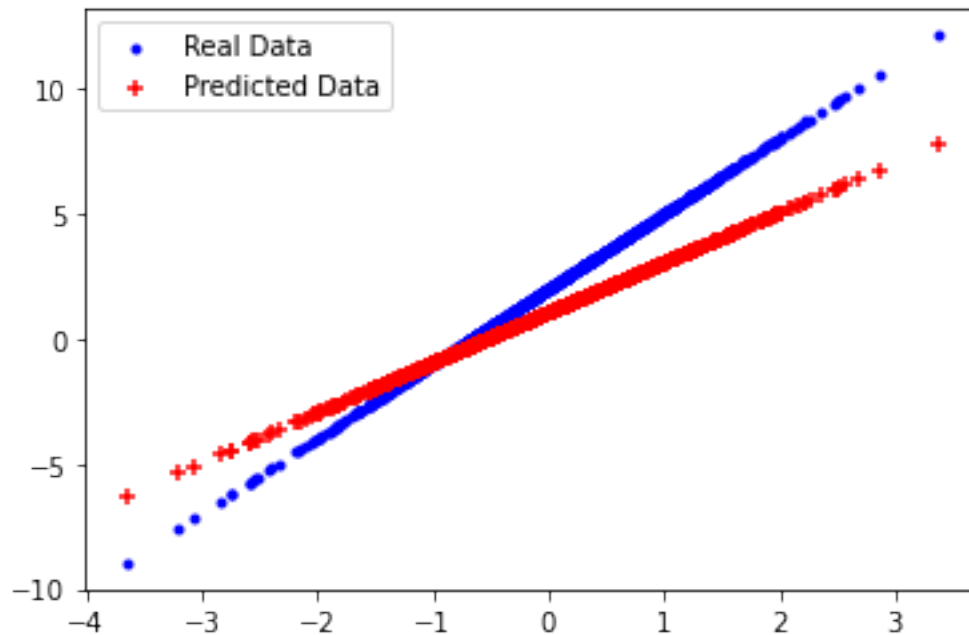
Before training the model, visualize the loss value by plotting the model's predictions in red crosses and the training data in blue dots:

```

[5]: def plot_data(inputs, outputs, predicted_outputs):
      real = plt.scatter(inputs, outputs, c='b', marker='.')
      predicted = plt.scatter(inputs, predicted_outputs, c='r', marker='+')
      plt.legend((real, predicted), ('Real Data', 'Predicted Data'))
      plt.show()

```

```
[6]: plot_data(xs, ys, model(xs))
      print('Current loss: %1.6f' % loss(model(xs), ys).numpy())
```



Current loss: 1.991555

### 1.2.3 Define a training loop

With the network and training data, train the model using [gradient descent](#) - Gradient descent updates the trainable weights  $\mathbf{w}$  and  $\mathbf{b}$  to reduce the loss.

There are many variants of the gradient descent scheme that are captured in `tf.train.Optimizer`—our recommended implementation. In the spirit of building from first principles, here you will implement the basic math yourself. - You'll use `tf.GradientTape` for automatic differentiation - Use `tf.assign_sub` for decrementing a value. Note that `assign_sub` combines `tf.assign` and `tf.sub`

```
[7]: def train(model, inputs, outputs, learning_rate):
      with tf.GradientTape() as t:
          current_loss = loss(model(inputs), outputs)
          dw, db = t.gradient(current_loss, [model.w, model.b])
          model.w.assign_sub(learning_rate * dw)
          model.b.assign_sub(learning_rate * db)

      return current_loss
```

Finally, you can iteratively run through the training data and see how  $\mathbf{w}$  and  $\mathbf{b}$  evolve.

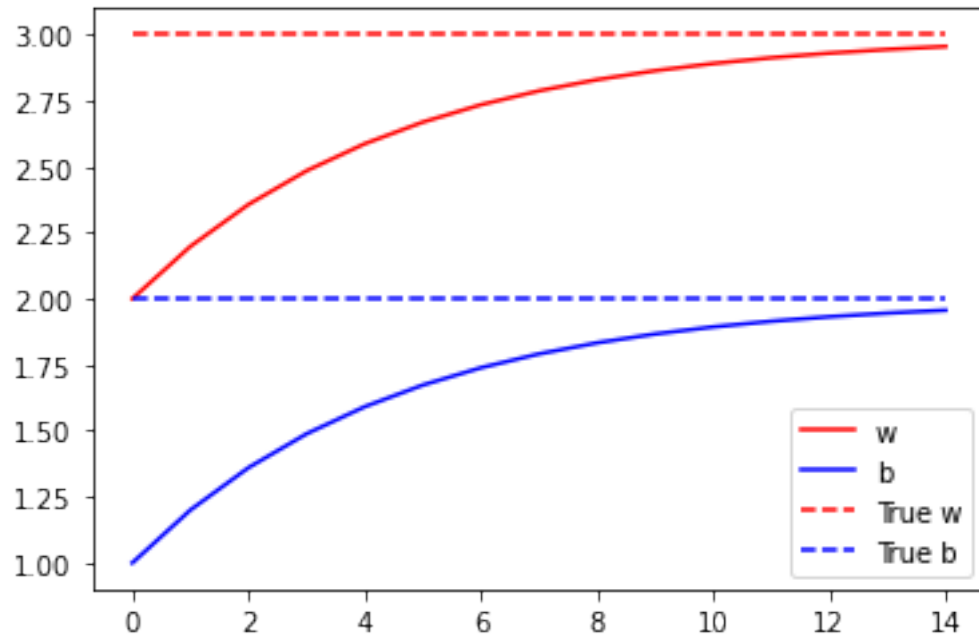
```
[8]: model = Model()

# Collect the history of W-values and b-values to plot later
list_w, list_b = [], []
epochs = range(15)
losses = []
for epoch in epochs:
    list_w.append(model.w.numpy())
    list_b.append(model.b.numpy())
    current_loss = train(model, xs, ys, learning_rate=0.1)
    losses.append(current_loss)
    print('Epoch %2d: w=%1.2f b=%1.2f, loss=%2.5f' %
          (epoch, list_w[-1], list_b[-1], current_loss))
```

```
Epoch 0: w=2.00 b=1.00, loss=1.99156
Epoch 1: w=2.20 b=1.20, loss=1.27727
Epoch 2: w=2.36 b=1.36, loss=0.81917
Epoch 3: w=2.48 b=1.49, loss=0.52538
Epoch 4: w=2.59 b=1.59, loss=0.33696
Epoch 5: w=2.67 b=1.67, loss=0.21611
Epoch 6: w=2.73 b=1.74, loss=0.13861
Epoch 7: w=2.79 b=1.79, loss=0.08890
Epoch 8: w=2.83 b=1.83, loss=0.05702
Epoch 9: w=2.86 b=1.87, loss=0.03657
Epoch 10: w=2.89 b=1.89, loss=0.02346
Epoch 11: w=2.91 b=1.91, loss=0.01504
Epoch 12: w=2.93 b=1.93, loss=0.00965
Epoch 13: w=2.94 b=1.95, loss=0.00619
Epoch 14: w=2.95 b=1.96, loss=0.00397
```

In addition to the values for losses, you also plot the progression of trainable variables over epochs.

```
[9]: plt.plot(epochs, list_w, 'r',
              epochs, list_b, 'b')
plt.plot([TRUE_w] * len(epochs), 'r--',
         [TRUE_b] * len(epochs), 'b--')
plt.legend(['w', 'b', 'True w', 'True b'])
plt.show()
```



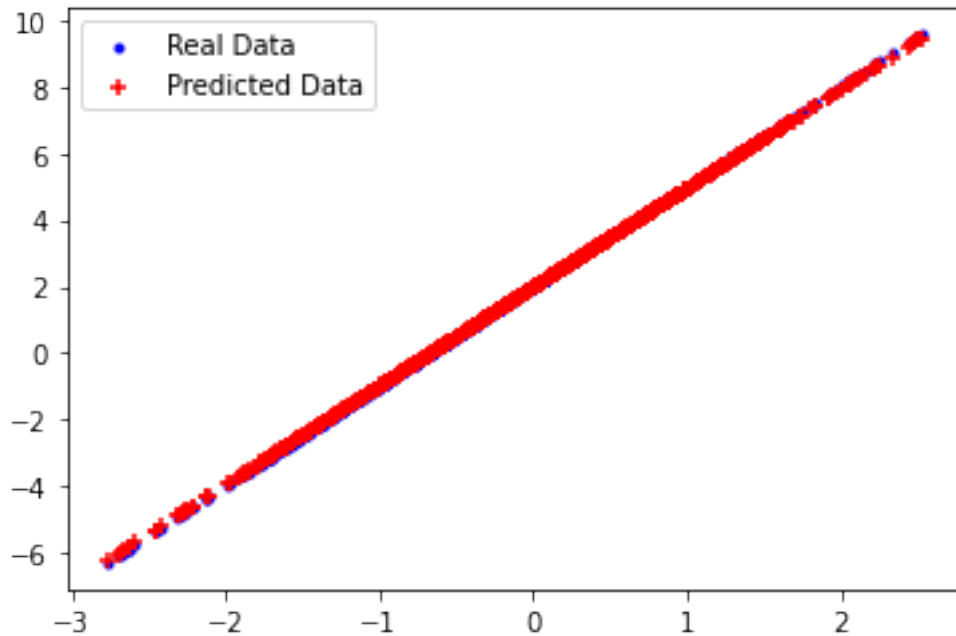
### 1.3 Plots for Evaluation

Now you can plot the actual outputs in red and the model's predictions in blue on a set of random test examples.

You can see that the model is able to make predictions on the test set fairly accurately.

```
[10]: test_inputs = tf.random.normal(shape=[NUM_EXAMPLES])
      test_outputs = test_inputs * TRUE_w + TRUE_b

      predicted_test_outputs = model(test_inputs)
      plot_data(test_inputs, test_outputs, predicted_test_outputs)
```



Visualize the cost function against the values of each of the trainable weights the model approximated to over time.

```
[11]: def plot_loss_for_weights(weights_list, losses):
    for idx, weights in enumerate(weights_list):
        plt.subplot(120 + idx + 1)
        plt.plot(weights['values'], losses, 'r')
        plt.plot(weights['values'], losses, 'bo')
        plt.xlabel(weights['name'])
        plt.ylabel('Loss')
```

```
weights_list = [{ 'name' : "w",
                   'values' : list_w
                 },
                 {
                   'name' : "b",
                   'values' : list_b
                 }
                ]
```

```
plot_loss_for_weights(weights_list, losses)
```

