ML0120EN-1.2-Review-LinearRegressionwithTensorFlow

October 17, 2020

LINEAR REGRESSION WITH TENSORFLOW

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Objective for this Notebook

1. What is Linear Regression
   2. Linear Regression with TensorFlow.

In this notebook we will overview the implementation of Linear Regression with TensorFlow

Table of Contents

Linear Regression

Defining a linear regression in simple terms, is the approximation of a linear model used to describe the relationship between two or more variables. In a simple linear regression there are two variables, the dependent variable, which can be seen as the “state” or “final goal” that we study and try to predict, and the independent variables, also known as explanatory variables, which can be seen as the “causes” of the “states”.

When more than one independent variable is present the process is called multiple linear regression. When multiple dependent variables are predicted the process is known as multivariate linear regression.

The equation of a simple linear model is

$$Y = aX + b$$

Where Y is the dependent variable and X is the independent variable, and a and b being the parameters we adjust. a is known as “slope” or “gradient” and b is the “intercept”. You can interpret this equation as Y being a function of X, or Y being dependent on X.

If you plot the model, you will see it is a line, and by adjusting the “slope” parameter you will change the angle between the line and the independent variable axis, and the “intercept parameter” will affect where it crosses the dependent variable’s axis.

We begin by installing TensorFlow version 2.2.0 and its required prerequistes.

[1]:

```
!pip install grpcio==1.24.3
!pip install tensorflow==2.2.0
```

```
Collecting grpcio==1.24.3
  Downloading https://files.pythonhosted.org/packages/30/54/c9810421e41ec0
bca2228c6f06b1b1189b196b69533cbcac9f71b44727f8/grpcio-1.24.3-cp36-cp36m-manylinu
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Requirement already satisfied: six>=1.5.2 in
/home/jupyterlab/conda/envs/python/lib/python3.6/site-packages (from
grpcio==1.24.3) (1.15.0)
Installing collected packages: grpcio
  Found existing installation: grpcio 1.31.0
    Uninstalling grpcio-1.31.0:
      Successfully uninstalled grpcio-1.31.0
Successfully installed grpcio-1.24.3
Collecting tensorflow==2.2.0
  Downloading https://files.pythonhosted.org/packages/3d/be/679ce5254a8c8d
07470efb4a4c00345fae91f766e64f1c2aece8796d7218/tensorflow-2.2.0-cp36-cp36m-manyl
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3-none-any.whl (454kB)
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tensorflow==2.2.0) (1.15.0)
Collecting scipy==1.4.1; python_version >= "3" (from tensorflow==2.2.0)
  Downloading https://files.pythonhosted.org/packages/dc/29/162476fd442031
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tensorflow==2.2.0) (0.10.0)
Requirement already satisfied: termcolor>=1.1.0 in
/home/jupyterlab/conda/envs/python/lib/python3.6/site-packages (from
tensorflow==2.2.0) (1.1.0)
Collecting gast==0.3.3 (from tensorflow==2.2.0)
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Requirement already satisfied: grpcio>=1.8.6 in
/home/jupyterlab/conda/envs/python/lib/python3.6/site-packages (from
tensorflow==2.2.0) (1.24.3)
Collecting h5py<2.11.0,>=2.10.0 (from tensorflow==2.2.0)
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Collecting tensorboard<2.3.0,>=2.2.0 (from tensorflow==2.2.0)
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tensorflow==2.2.0) (1.19.1)
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tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0) (1.0.1)
Requirement already satisfied: requests<3,>=2.21.0 in
/home/jupyterlab/conda/envs/python/lib/python3.6/site-packages (from
tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0) (2.24.0)
Collecting google-auth-oauthlib<0.5,>=0.4.1 (from
tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0)
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-any.whl
Collecting google-auth<2,>=1.6.3 (from
tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0)
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Collecting tensorboard-plugin-wit>=1.6.0 (from
tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0)
  Downloading https://files.pythonhosted.org/packages/b6/85/5c5ac0a8c5efdf
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Requirement already satisfied: idna<3,>=2.5 in
/home/jupyterlab/conda/envs/python/lib/python3.6/site-packages (from
requests<3,>=2.21.0->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0) (2.10)
Requirement already satisfied: certifi>=2017.4.17 in
/home/jupyterlab/conda/envs/python/lib/python3.6/site-packages (from
requests<3,>=2.21.0->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0) (2020.6.20)
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in
/home/jupyterlab/conda/envs/python/lib/python3.6/site-packages (from
requests<3,>=2.21.0->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0) (1.25.10)
Requirement already satisfied: chardet<4,>=3.0.2 in
/home/jupyterlab/conda/envs/python/lib/python3.6/site-packages (from
requests<3,>=2.21.0->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0) (3.0.4)
Collecting requests-oauthlib>=0.7.0 (from google-auth-
oauthlib<0.5,>=0.4.1->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0)
  Using cached https://files.pythonhosted.org/packages/a3/12/b92740d845ab62ea4ed
f04d2f4164d82532b5a0b03836d4d4e71c6f3d379/requests_oauthlib-1.3.0-py2.py3-none-
any.whl
Collecting cachetools<5.0,>=2.0.0 (from google-
auth<2,>=1.6.3->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0)
  Using cached https://files.pythonhosted.org/packages/cd/5c/f3aa86b6d5482f3051b
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Requirement already satisfied: pyasn1-modules>=0.2.1 in
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auth<2,>=1.6.3->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0) (0.2.8)
Collecting rsa<5,>=3.1.4; python_version >= "3.5" (from google-
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Requirement already satisfied: importlib-metadata; python_version < "3.8" in
/home/jupyterlab/conda/envs/python/lib/python3.6/site-packages (from
markdown>=2.6.8->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0) (2.0.0)
Collecting oauthlib>=3.0.0 (from requests-oauthlib>=0.7.0->google-auth-
oauthlib<0.5,>=0.4.1->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0)
  Downloading https://files.pythonhosted.org/packages/05/57/ce2e7a8fa7c0af
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Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in
/home/jupyterlab/conda/envs/python/lib/python3.6/site-packages (from
pyasn1-modules>=0.2.1->google-
auth<2,>=1.6.3->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0) (0.4.8)
Requirement already satisfied: zipp>=0.5 in
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```
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metadata; python_version <
"3.8"->markdown>=2.6.8->tensorboard<2.3.0,>=2.2.0->tensorflow==2.2.0) (3.2.0)
Building wheels for collected packages: wrapt
  Building wheel for wrapt (setup.py) … done
  Stored in directory: /home/jupyterlab/.cache/pip/wheels/b1/c2/ed/d622082
60edbd3fa7156545c00ef966f45f2063d0a84f8208a
Successfully built wrapt
Installing collected packages: google-pasta, tensorflow-estimator, scipy, gast,
h5py, oauthlib, requests-oauthlib, cachetools, rsa, google-auth, google-auth-
oauthlib, tensorboard-plugin-wit, tensorboard, keras-preprocessing, wrapt, opt-
einsum, astunparse, tensorflow
  Found existing installation: scipy 1.5.2
    Uninstalling scipy-1.5.2:
      Successfully uninstalled scipy-1.5.2
  Found existing installation: gast 0.4.0
    Uninstalling gast-0.4.0:
      Successfully uninstalled gast-0.4.0
  Found existing installation: h5py 2.8.0
    Uninstalling h5py-2.8.0:
      Successfully uninstalled h5py-2.8.0
  Found existing installation: tensorboard 1.8.0
    Uninstalling tensorboard-1.8.0:
      Successfully uninstalled tensorboard-1.8.0
  Found existing installation: tensorflow 1.8.0
    Uninstalling tensorflow-1.8.0:
      Successfully uninstalled tensorflow-1.8.0
Successfully installed astunparse-1.6.3 cachetools-4.1.1 gast-0.3.3 google-
auth-1.22.1 google-auth-oauthlib-0.4.1 google-pasta-0.2.0 h5py-2.10.0 keras-
preprocessing-1.1.2 oauthlib-3.1.0 opt-einsum-3.3.0 requests-oauthlib-1.3.0
rsa-4.6 scipy-1.4.1 tensorboard-2.2.2 tensorboard-plugin-wit-1.7.0
tensorflow-2.2.0 tensorflow-estimator-2.2.0 wrapt-1.12.1
```

Restart kernel for latest version of TensorFlow to be activated

Next, let's first import the required packages:

[2]:

```python
import tensorflow as tf
import numpy as np
import pandas as pd
import pylab as pl
import matplotlib.patches as mpatches
import matplotlib.pyplot as plt
%matplotlib inline
plt.rcParams['figure.figsize'] = (10, 6)
```

[3]:

```python
if not tf.__version__ == '2.2.0':
    print(tf.__version__)
    raise ValueError('please upgrade to TensorFlow 2.2.0, or restart your␣
↪Kernel (Kernel->Restart & Clear Output)')
```

IMPORTANT! => Please restart the kernel by clicking on “Kernel”->“Restart and Clear Outout” and wait until all output disapears. Then your changes are beeing picked up

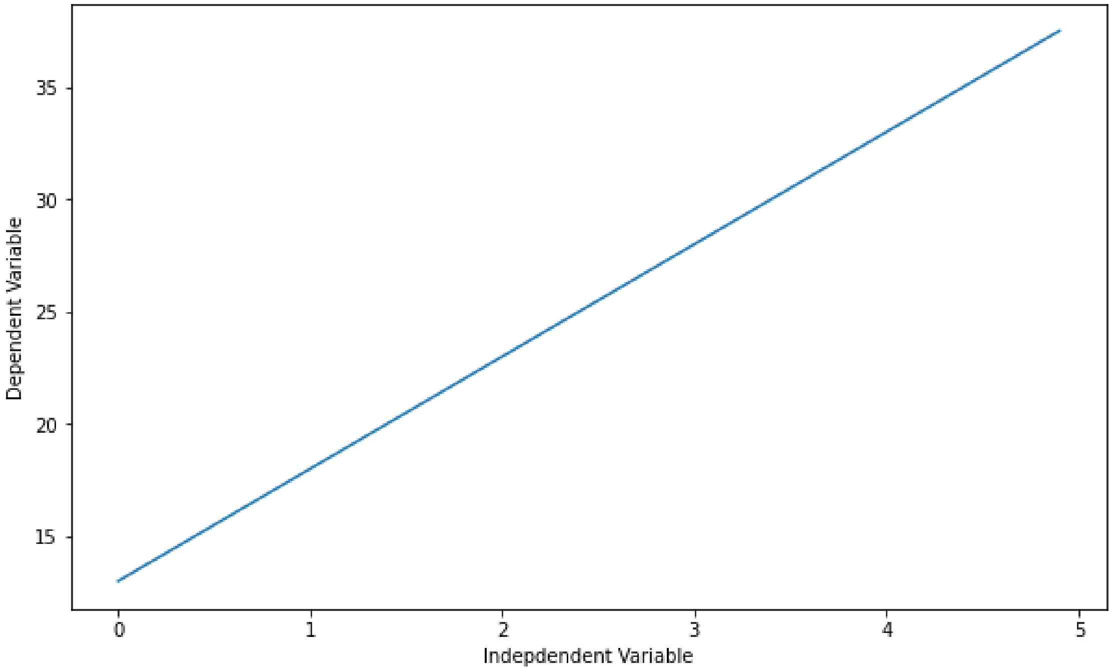
Let’s define the independent variable:

[4]:
```
X = np.arange(0.0, 5.0, 0.1)
X
```

[4]:
```
array([0. , 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1. , 1.1, 1.2,
       1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2. , 2.1, 2.2, 2.3, 2.4, 2.5,
       2.6, 2.7, 2.8, 2.9, 3. , 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8,
       3.9, 4. , 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9])
```

[6]:
```
a = 5
b = 13
Y = a * X + b

plt.plot(X, Y)
plt.ylabel('Dependent Variable')
plt.xlabel('Indepdendent Variable')
plt.show()
```



OK… but how can we see this concept of linear relations with a more meaningful point of view?

Simple linear relations were used to try to describe and quantify many observable physical phenomena, the easiest to understand are speed and distance traveled:

$$DistanceTraveled = SpeedtimesTime + InitialDistance$$

$$Speed = AccelerationtimesTime + InitialSpeed$$

They are also used to describe properties of different materials:

$$Force = DeformationtimesStiffness$$

$$HeatTransfered = TemperatureDifferencetimesThermalConductivity$$

$$ElectricalTension(Voltage) = ElectricalCurrenttimesResistance$$

$$Mass = VolumetimesDensity$$

When we perform an experiment and gather the data, or if we already have a dataset and we want to perform a linear regression, what we will do is adjust a simple linear model to the dataset, we adjust the "slope" and "intercept" parameters to the data the best way possible, because the closer the model comes to describing each ocurrence, the better it will be at representing them.

So how is this "regression" performed?

Linear Regression with TensorFlow

A simple example of a linear function can help us understand the basic mechanism behind TensorFlow.

For the first part we will use a sample dataset, and then we'll use TensorFlow to adjust and get the right parameters. We download a dataset that is related to fuel consumption and Carbon dioxide emission of cars.

[7]:
```
!wget -O FuelConsumption.csv https://s3-api.us-geo.objectstorage.softlayer.net/
 ↪cf-courses-data/CognitiveClass/ML0101ENv3/labs/FuelConsumptionCo2.csv
```

```
--2020-10-17 01:09:26--  https://s3-api.us-geo.objectstorage.softlayer.net/cf-
courses-data/CognitiveClass/ML0101ENv3/labs/FuelConsumptionCo2.csv
Resolving s3-api.us-geo.objectstorage.softlayer.net (s3-api.us-
geo.objectstorage.softlayer.net)… 67.228.254.196
Connecting to s3-api.us-geo.objectstorage.softlayer.net (s3-api.us-
geo.objectstorage.softlayer.net)|67.228.254.196|:443… connected.
HTTP request sent, awaiting response… 200 OK
Length: 72629 (71K) [text/csv]
Saving to: 'FuelConsumption.csv'
```

```
FuelConsumption.csv 100%[===================>]  70.93K  --.-KB/s    in 0.06s

2020-10-17 01:09:26 (1.26 MB/s) - ‘FuelConsumption.csv’ saved [72629/72629]
```

Understanding the Data

FuelConsumption.csv:

We have downloaded a fuel consumption dataset, FuelConsumption.csv, which contains model-specific fuel consumption ratings and estimated carbon dioxide emissions for new light-duty vehicles for retail sale in Canada. Dataset source

- **MODELYEAR** e.g. 2014
- **MAKE** e.g. Acura
- **MODEL** e.g. ILX
- **VEHICLE CLASS** e.g. SUV
- **ENGINE SIZE** e.g. 4.7
- **CYLINDERS** e.g 6
- **TRANSMISSION** e.g. A6
- **FUEL CONSUMPTION in CITY(L/100 km)** e.g. 9.9
- **FUEL CONSUMPTION in HWY (L/100 km)** e.g. 8.9
- **FUEL CONSUMPTION COMB (L/100 km)** e.g. 9.2
- **CO2 EMISSIONS (g/km)** e.g. 182 –> low –> 0

[8]:
```
df = pd.read_csv("FuelConsumption.csv")
df.head()
```

[8]:
```
   MODELYEAR   MAKE       MODEL VEHICLECLASS  ENGINESIZE  CYLINDERS   \
0       2014  ACURA         ILX      COMPACT         2.0          4
1       2014  ACURA         ILX      COMPACT         2.4          4
2       2014  ACURA  ILX HYBRID      COMPACT         1.5          4
3       2014  ACURA     MDX 4WD  SUV - SMALL         3.5          6
4       2014  ACURA     RDX AWD  SUV - SMALL         3.5          6

  TRANSMISSION FUELTYPE  FUELCONSUMPTION_CITY  FUELCONSUMPTION_HWY   \
0          AS5        Z                   9.9                  6.7
1           M6        Z                  11.2                  7.7
2          AV7        Z                   6.0                  5.8
3          AS6        Z                  12.7                  9.1
4          AS6        Z                  12.1                  8.7

   FUELCONSUMPTION_COMB  FUELCONSUMPTION_COMB_MPG  CO2EMISSIONS
0                   8.5                        33           196
1                   9.6                        29           221
2                   5.9                        48           136
3                  11.1                        25           255
4                  10.6                        27           244
```

Lets say we want to use linear regression to predict Co2Emission of cars based on their engine size. So, lets define X and Y value for the linear regression, that is, train_x and train_y:

[9]:
```
train_x = np.asanyarray(df[['ENGINESIZE']])
train_y = np.asanyarray(df[['CO2EMISSIONS']])
```

First, we initialize the variables a and b, with any random guess, and then we define the linear function:

[18]:
```
a = tf.Variable(np.random.rand())
b = tf.Variable(np.random.rand())

def h(x):
   y = a*x + b
   return y
```

Now, we are going to define a loss function for our regression, so we can train our model to better fit our data. In a linear regression, we minimize the squared error of the difference between the predicted values(obtained from the equation) and the target values (the data that we have). In other words we want to minimize the square of the predicted values minus the target value. So we define the equation to be minimized as loss.

To find value of our loss, we use tf.reduce_mean(). This function finds the mean of a multidimensional tensor, and the result can have a different dimension.

[20]:
```
def loss_object(y,train_y) :
    return tf.reduce_mean(tf.square(y - train_y))

loss_object_TF = tf.keras.losses.MeanSquaredLogarithmicError() # predefined␣
 ↪method offered by TensorFlow to calculate loss function
```

Now we are ready to start training and run the graph. We use GradientTape to calculate gradients:

[21]:
```
learning_rate = 0.01
train_data = []
loss_values =[]
training_epochs = 200

for epoch in range(training_epochs):
    with tf.GradientTape() as tape:
        y_predicted = h(train_x)
        loss_value = loss_object(train_y,y_predicted)
        loss_values.append(loss_value)
        gradients = tape.gradient(loss_value, [b,a])
        b.assign_sub(gradients[0]*learning_rate)
        a.assign_sub(gradients[1]*learning_rate)
        if epoch % 5 == 0:
            train_data.append([a, b])
```

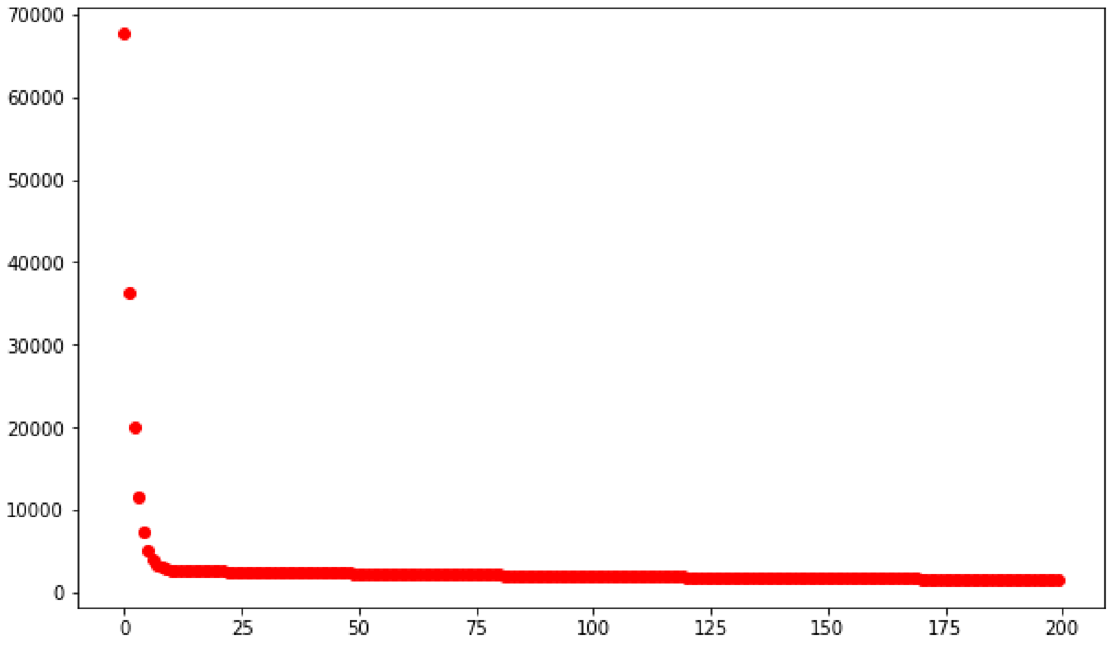
Lets plot the loss values to see how it has changed during the training:

[22]:

```
plt.plot(loss_values, 'ro')
```

[22]:

```
[<matplotlib.lines.Line2D at 0x7f96c48f43c8>]
```



Lets visualize how the coefficient and intercept of line has changed to fit the data:

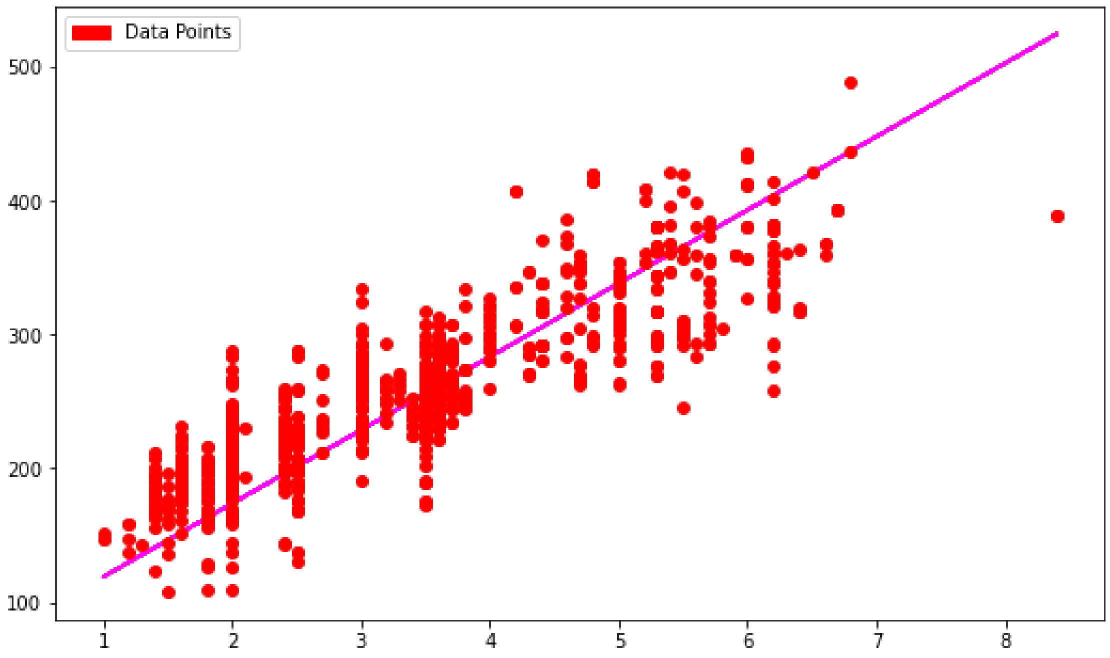
[23]:

```
cr, cg, cb = (1.0, 1.0, 0.0)
for f in train_data:
    cb += 1.0 / len(train_data)
    cg -= 1.0 / len(train_data)
    if cb > 1.0: cb = 1.0
    if cg < 0.0: cg = 0.0
    [a, b] = f
    f_y = np.vectorize(lambda x: a*x + b)(train_x)
    line = plt.plot(train_x, f_y)
    plt.setp(line, color=(cr,cg,cb))

plt.plot(train_x, train_y, 'ro')
green_line = mpatches.Patch(color='red', label='Data Points')

plt.legend(handles=[green_line])

plt.show()
```



0.1 Want to learn more?

Running deep learning programs usually needs a high performance platform. **PowerAI** speeds up deep learning and AI. Built on IBM's Power Systems, **PowerAI** is a scalable software platform that accelerates deep learning and AI with blazing performance for individual users or enterprises. The **PowerAI** platform supports popular machine learning libraries and dependencies including TensorFlow, Caffe, Torch, and Theano. You can use PowerAI on IMB Cloud.

Also, you can use **Watson Studio** to run these notebooks faster with bigger datasets.**Watson Studio** is IBM's leading cloud solution for data scientists, built by data scientists. With Jupyter notebooks, RStudio, Apache Spark and popular libraries pre-packaged in the cloud, **Watson Studio** enables data scientists to collaborate on their projects without having to install anything. Join the fast-growing community of **Watson Studio** users today with a free account at Watson Studio.This is the end of this lesson. Thank you for reading this notebook, and good luck on your studies.

0.1.1 Thanks for completing this lesson!

If you are familiar with some of these methods and concepts, this tutorial might have been boring for you, but it is important to get used to the TensorFlow mechanics, and feel familiar and comfortable using it, so you can build more complex algorithms in it.

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Updated to TF 2.X by Samaya Madhavan

0.2 Change Log

Date (YYYY-MM-DD)	Version	Changed By	Change Description
2020-09-21	2.0	Srishti	Migrated Lab to Markdown and added to course repo in GitLab

##