In [0]:

```
# Credits: https://github.com/SullyChen/Autopilot-TensorFlow
# Research paper: End to End Learning for Self-Driving Cars by Nvidia. [https://a

# NVidia dataset: 72 hrs of video => 72*60*60*30 = 7,776,000 images
# Nvidia blog: https://devblogs.nvidia.com/deep-learning-self-driving-cars/


# Our Dataset: https://github.com/SullyChen/Autopilot-TensorFlow [https://drive.g
# Size: 25 minutes = 25*60*30 = 45,000 images ~ 2.3 GB


# If you want to try on a slightly large dataset: 70 minutes of data ~ 223GB
# Refer: https://medium.com/udacity/open-sourcing-223gb-of-mountain-view-driving-
# Format: Image, latitude, longitude, gear, brake, throttle, steering angles and 



# Additional Installations:
# pip3 install h5py


# AWS: https://aws.amazon.com/blogs/machine-learning/get-started-with-deep-learni

# Youtube:https://www.youtube.com/watch?v=qhUvQiKec2U
# Further reading and extensions: https://medium.com/udacity/teaching-a-machine-t
# More data: https://medium.com/udacity/open-sourcing-223gb-of-mountain-view-driv
```

In [1]:

```
# read images and steering angles from driving_dataset folder

from __future__ import division

import os
import numpy as np
import random

from scipy import pi
from itertools import islice



DATA_FOLDER = 'driving_dataset' # change this to your folder
TRAIN_FILE = os.path.join(DATA_FOLDER, 'data.txt')


split =0.7
X = []
y = []
LIMIT=None
with open(TRAIN_FILE) as fp:
    for line in islice(fp,LIMIT):
        path, angle = line.strip().split()
        full_path = os.path.join(DATA_FOLDER, path)
        X.append(full_path)

        # converting angle from degrees to radians
        y.append(float(angle) * pi / 180 )


y = np.array(y)
print("Completed processing data.txt")

split_index = int(len(y)*0.7)

train_y = y[:split_index]
test_y = y[split_index:]
```

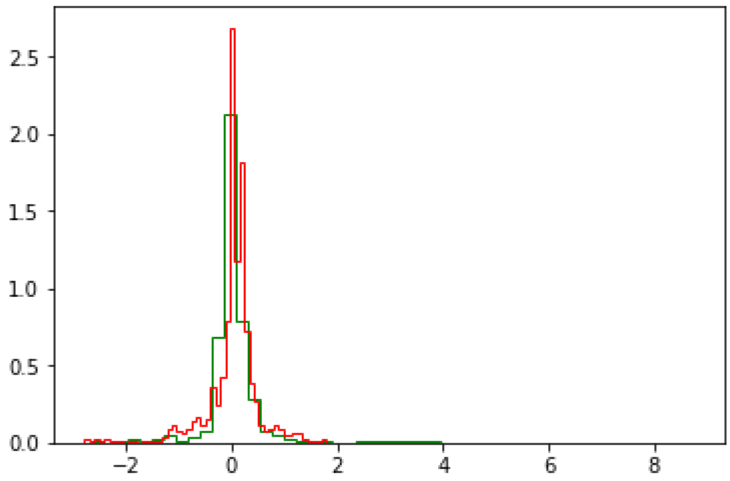
```
Completed processing data.txt
```

In [3]:

```
import numpy;

# PDF of train and test 'y' values.
import matplotlib.pyplot as plt
plt.hist(train_y, bins=50, normed=1, color='green', histtype ='step');
plt.hist(test_y, bins=50, normed=1, color='red', histtype ='step');
plt.show()
```

```
C:\Users\1407244\Anaconda3\lib\site-packages\matplotlib\axes\_axes.py:6462: Use
rWarning: The 'normed' kwarg is deprecated, and has been replaced by the 'densi
ty' kwarg.
  warnings.warn("The 'normed' kwarg is deprecated, and has been "
```



In [4]:

```
#Model 0: Base line Model: y_test_pred = mean(y_train_i)
train_mean_y = np.mean(train_y)

print('Test_MSE(MEAN):%f' % np.mean(np.square(test_y-train_mean_y)) )

print('Test_MSE(ZERO):%f' % np.mean(np.square(test_y-0.0)) )
```

```
Test_MSE(MEAN):0.241561
Test_MSE(ZERO):0.241107
```

Splitting the data

In [5]:

```
import scipy.misc
import random

xs = []
ys = []

#points to the end of the last batch
train_batch_pointer = 0
val_batch_pointer = 0

#read data.txt
with open("driving_dataset/data.txt") as f:
    for line in f:
        xs.append("driving_dataset/" + line.split()[0])
        #the paper by Nvidia uses the inverse of the turning radius,
        #but steering wheel angle is proportional to the inverse of turning radiu
        #so the steering wheel angle in radians is used as the output
        ys.append(float(line.split()[1]) * scipy.pi / 180)

#get number of images
num_images = len(xs)


train_xs = xs[:int(len(xs) * 0.7)]
train_ys = ys[:int(len(xs) * 0.7)]

val_xs = xs[-int(len(xs) * 0.3):]
val_ys = ys[-int(len(xs) * 0.3):]

num_train_images = len(train_xs)
num_val_images = len(val_xs)

def LoadTrainBatch(batch_size):
    global train_batch_pointer
    x_out = []
    y_out = []
    for i in range(0, batch_size):
        x_out.append(scipy.misc.imresize(scipy.misc.imread(train_xs[(train_batch_
        y_out.append([train_ys[(train_batch_pointer + i) % num_train_images]])
    train_batch_pointer += batch_size
    return x_out, y_out

def LoadValBatch(batch_size):
    global val_batch_pointer
    x_out = []
    y_out = []
    for i in range(0, batch_size):
        x_out.append(scipy.misc.imresize(scipy.misc.imread(val_xs[(val_batch_poin
        y_out.append([val_ys[(val_batch_pointer + i) % num_val_images]])
    val_batch_pointer += batch_size
    return x_out, y_out
```

In [6]:

```
# scipy.misc.imresize(scipy.misc.imread(train_xs[(train_batch_pointer + i) % num_
# you can break the whole line into parts like this
# here (train_batch_pointer + i) % num_train_images => "% num_train_images" is us
# (train_batch_pointer + i) values should not cross number of train images.

# lets explain whats happening with the first images
image_read = scipy.misc.imread(train_xs[0])
print("original image size",image_read.shape)

print("After taking the last 150 rows i.e lower part of the images where road is
image_read = image_read[-150:]
resized_image = scipy.misc.imresize(image_read, [66, 200])
print("After resizing the images into 66*200, ",resized_image.shape)
# 200/66 = 455/150 = 3.0303 => we are keeping aspect ratio when we are resizing i
```

```
C:\Users\1407244\Anaconda3\lib\site-packages\ipykernel_launcher.py:7: Deprecati
onWarning: `imread` is deprecated!
`imread` is deprecated in SciPy 1.0.0, and will be removed in 1.2.0.
Use ``imageio.imread`` instead.
  import sys

original image size (256, 455, 3)
After taking the last 150 rows i.e lower part of the images where road is prese
nt,  (150, 455, 3)
After resizing the images into 66*200,  (66, 200, 3)

C:\Users\1407244\Anaconda3\lib\site-packages\ipykernel_launcher.py:12: Deprecat
ionWarning: `imresize` is deprecated!
`imresize` is deprecated in SciPy 1.0.0, and will be removed in 1.2.0.
Use ``skimage.transform.resize`` instead.
  if sys.path[0] == '':
```

In [0]:
```
scipy.misc.imresize(scipy.misc.imread(train_xs[0])[-150:], [66, 200])
```

```
D:\installed\Anaconda3\lib\site-packages\ipykernel_launcher.py:1: DeprecationWa
rning: `imread` is deprecated!
`imread` is deprecated in SciPy 1.0.0, and will be removed in 1.2.0.
Use ``imageio.imread`` instead.
  """Entry point for launching an IPython kernel.
D:\installed\Anaconda3\lib\site-packages\ipykernel_launcher.py:1: DeprecationWa
rning: `imresize` is deprecated!
`imresize` is deprecated in SciPy 1.0.0, and will be removed in 1.2.0.
Use ``skimage.transform.resize`` instead.
  """Entry point for launching an IPython kernel.
```

Out[6]:
```
array([[[180, 162, 166],
        [176, 172, 173],
        [176, 176, 171],
        ...,
        [ 90,  88, 113],
        [106,  93,  99],
        [101, 103,  81]],

       [[191, 188, 192],
        [186, 193, 204],
        [187, 196, 200],
        ...,
        [ 84,  82,  97],
        [ 86,  88,  79],
        [ 86, 101,  74]],

       [[208, 201, 223],
        [199, 212, 230],
        [201, 212, 226],
        ...,
        [128, 124, 115],
        [128, 126, 117],
        [132, 126, 119]],

       ...,

       [[ 54,  43,  55],
        [ 59,  43,  56],
        [ 55,  41,  53],
        ...,
        [ 23,  24,  25],
        [ 24,  25,  27],
        [ 25,  26,  29]],

       [[ 56,  36,  58],
        [ 53,  35,  63],
        [ 51,  39,  54],
        ...,
        [ 23,  25,  22],
        [ 23,  26,  23],
        [ 24,  27,  25]],

       [[ 68,  37,  44],
        [ 53,  41,  49],
        [ 49,  49,  37],
        ...,
        [ 28,  25,  26],
        [ 26,  23,  25],
        [ 24,  22,  24]]], dtype=uint8)
```

In [6]:

```
xs
```

Out[6]:

```
['driving_dataset/0.jpg',
 'driving_dataset/1.jpg',
 'driving_dataset/2.jpg',
 'driving_dataset/3.jpg',
 'driving_dataset/4.jpg',
 'driving_dataset/5.jpg',
 'driving_dataset/6.jpg',
 'driving_dataset/7.jpg',
 'driving_dataset/8.jpg',
 'driving_dataset/9.jpg',
 'driving_dataset/10.jpg',
 'driving_dataset/11.jpg',
 'driving_dataset/12.jpg',
 'driving_dataset/13.jpg',
 'driving_dataset/14.jpg',
 'driving_dataset/15.jpg',
 'driving_dataset/16.jpg',
 'driving_dataset/17.jpg',
 'driving_dataset/18.jpg',
```

Defining CNN Model

In [6]:

```
import tensorflow as tf
import scipy

def weight_variable(shape):
  initial = tf.truncated_normal(shape, stddev=0.1)
  return tf.Variable(initial)

def bias_variable(shape):
  initial = tf.constant(0.1, shape=shape)
  return tf.Variable(initial)

def conv2d(x, W, stride):
  return tf.nn.conv2d(x, W, strides=[1, stride, stride, 1], padding='VALID')

x = tf.placeholder(tf.float32, shape=[None, 66, 200, 3])
y_ = tf.placeholder(tf.float32, shape=[None, 1])

x_image = x

#first convolutional layer
W_conv1 = weight_variable([5, 5, 3, 24])
b_conv1 = bias_variable([24])

h_conv1 = tf.nn.relu(conv2d(x_image, W_conv1, 2) + b_conv1)

#second convolutional layer
W_conv2 = weight_variable([5, 5, 24, 36])
b_conv2 = bias_variable([36])

h_conv2 = tf.nn.relu(conv2d(h_conv1, W_conv2, 2) + b_conv2)

#third convolutional layer
W_conv3 = weight_variable([5, 5, 36, 48])
b_conv3 = bias_variable([48])

h_conv3 = tf.nn.relu(conv2d(h_conv2, W_conv3, 2) + b_conv3)

#fourth convolutional layer
W_conv4 = weight_variable([3, 3, 48, 64])
b_conv4 = bias_variable([64])

h_conv4 = tf.nn.relu(conv2d(h_conv3, W_conv4, 1) + b_conv4)

#fifth convolutional layer
W_conv5 = weight_variable([3, 3, 64, 64])
b_conv5 = bias_variable([64])

h_conv5 = tf.nn.relu(conv2d(h_conv4, W_conv5, 1) + b_conv5)

#FCL 1
W_fc1 = weight_variable([1152, 1164])
b_fc1 = bias_variable([1164])

h_conv5_flat = tf.reshape(h_conv5, [-1, 1152])
h_fc1 = tf.nn.relu(tf.matmul(h_conv5_flat, W_fc1) + b_fc1)
```

```
keep_prob = tf.placeholder(tf.float32)
h_fc1_drop = tf.nn.dropout(h_fc1, keep_prob)

#FCL 2
W_fc2 = weight_variable([1164, 100])
b_fc2 = bias_variable([100])

h_fc2 = tf.nn.relu(tf.matmul(h_fc1_drop, W_fc2) + b_fc2)

h_fc2_drop = tf.nn.dropout(h_fc2, keep_prob)

#FCL 3
W_fc3 = weight_variable([100, 50])
b_fc3 = bias_variable([50])

h_fc3 = tf.nn.relu(tf.matmul(h_fc2_drop, W_fc3) + b_fc3)

h_fc3_drop = tf.nn.dropout(h_fc3, keep_prob)

#FCL 3
W_fc4 = weight_variable([50, 10])
b_fc4 = bias_variable([10])

h_fc4 = tf.nn.relu(tf.matmul(h_fc3_drop, W_fc4) + b_fc4)

h_fc4_drop = tf.nn.dropout(h_fc4, keep_prob)

#Output
W_fc5 = weight_variable([10, 1])
b_fc5 = bias_variable([1])

y = tf.multiply(tf.tanh(tf.matmul(h_fc4_drop, W_fc5) + b_fc5), 2) #scale the atan
```

```
C:\Users\1407244\Anaconda3\lib\site-packages\h5py\__init__.py:36: FutureWarnin
g: Conversion of the second argument of issubdtype from `float` to `np.floating
` is deprecated. In future, it will be treated as `np.float64 == np.dtype(floa
t).type`.
  from ._conv import register_converters as _register_converters
```

In [7]:

```
import os
import tensorflow as tf
from tensorflow.core.protobuf import saver_pb2
import driving_data
import model

LOGDIR = './save'

sess = tf.InteractiveSession()

L2NormConst = 0.001

train_vars = tf.trainable_variables()

loss = tf.reduce_mean(tf.square(tf.subtract(model.y_, model.y))) + tf.add_n([tf.n
train_step = tf.train.RMSPropOptimizer(1e-4).minimize(loss)
sess.run(tf.initialize_all_variables())

# create a summary to monitor cost tensor
tf.summary.scalar("loss", loss)
# merge all summaries into a single op
merged_summary_op =  tf.summary.merge_all()

saver = tf.train.Saver(write_version = saver_pb2.SaverDef.V1)

# op to write logs to Tensorboard
logs_path = './logs'
summary_writer = tf.summary.FileWriter(logs_path, graph=tf.get_default_graph())

epochs = 30
batch_size = 100

# train over the dataset about 30 times
for epoch in range(epochs):
  for i in range(int(driving_data.num_images/batch_size)):
    xs, ys = driving_data.LoadTrainBatch(batch_size)
    train_step.run(feed_dict={model.x: xs, model.y_: ys, model.keep_prob: 0.8})
    if i % 10 == 0:
      xs, ys = driving_data.LoadValBatch(batch_size)
      loss_value = loss.eval(feed_dict={model.x:xs, model.y_: ys, model.keep_prob
      print("Epoch: %d, Step: %d, Loss: %g" % (epoch, epoch * batch_size + i, los

    # write logs at every iteration
    summary = merged_summary_op.eval(feed_dict={model.x:xs, model.y_: ys, model.k
    summary_writer.add_summary(summary, epoch * driving_data.num_images/batch_siz

    if i % batch_size == 0:
      if not os.path.exists(LOGDIR):
        os.makedirs(LOGDIR)
      checkpoint_path = os.path.join(LOGDIR, "model.ckpt")
      filename = saver.save(sess, checkpoint_path)
  print("Model saved in file: %s" % filename)

print("Run the command line:\n" \
          "--> tensorboard --logdir=./logs " \
          "\nThen open http://0.0.0.0:6006/ into your web browser")
```

```
Epoch: 29, Step: 3260, Loss: 0.237199
Epoch: 29, Step: 3270, Loss: 0.170799
Epoch: 29, Step: 3280, Loss: 0.17891
Epoch: 29, Step: 3290, Loss: 0.0822371
Epoch: 29, Step: 3300, Loss: 0.0841137
WARNING:tensorflow:*******************************************************
WARNING:tensorflow:TensorFlow's V1 checkpoint format has been deprecated.
WARNING:tensorflow:Consider switching to the more efficient V2 format:
WARNING:tensorflow:   `tf.train.Saver(write_version=tf.train.SaverDef.V2)`
WARNING:tensorflow:now on by default.
WARNING:tensorflow:*******************************************************
Epoch: 29, Step: 3310, Loss: 0.0954492
Epoch: 29, Step: 3320, Loss: 0.0823915
Epoch: 29, Step: 3330, Loss: 0.0903439
Epoch: 29, Step: 3340, Loss: 0.104802
Epoch: 29, Step: 3350, Loss: 0.0813528
Model saved in file: ./save\model.ckpt
Run the command line:
--> tensorboard --logdir=./logs
Then open http://0.0.0.0:6006/ (http://0.0.0.0:6006/) into your web browser
```

In [8]:

```
#pip3 install opencv-python

import tensorflow as tf
import scipy.misc
import model
import cv2
from subprocess import call
import math

sess = tf.InteractiveSession()
saver = tf.train.Saver()
saver.restore(sess, "save/model.ckpt")

img = cv2.imread('steering_wheel_image.jpg',0)
rows,cols = img.shape

smoothed_angle = 0


#read data.txt
xs = []
ys = []
with open("driving_dataset/data.txt") as f:
    for line in f:
        xs.append("driving_dataset/" + line.split()[0])
        #the paper by Nvidia uses the inverse of the turning radius,
        #but steering wheel angle is proportional to the inverse of turning radiu
        #so the steering wheel angle in radians is used as the output
        ys.append(float(line.split()[1]) * scipy.pi / 180)

#get number of images
num_images = len(xs)


i = math.ceil(num_images*0.8)
print("Starting frameofvideo:" +str(i))

while(cv2.waitKey(10) != ord('q')):
    full_image = scipy.misc.imread("driving_dataset/" + str(i) + ".jpg", mode="RG
    image = scipy.misc.imresize(full_image[-150:], [66, 200]) / 255.0
    degrees = model.y.eval(feed_dict={model.x: [image], model.keep_prob: 1.0})[0]
    #call("clear")
    #print("Predicted Steering angle: " + str(degrees))
    print("Steering angle: " + str(degrees) + " (pred)\t" + str(ys[i]*180/scipy.p
    cv2.imshow("frame", cv2.cvtColor(full_image, cv2.COLOR_RGB2BGR))
    #make smooth angle transitions by turning the steering wheel based on the dif
    #and the predicted angle
    smoothed_angle += 0.2 * pow(abs((degrees - smoothed_angle)), 2.0 / 3.0) * (de
    M = cv2.getRotationMatrix2D((cols/2,rows/2),-smoothed_angle,1)
    dst = cv2.warpAffine(img,M,(cols,rows))
    cv2.imshow("steering wheel", dst)
    i += 1

cv2.destroyAllWindows()
```

```
Steering angle: 6.237555853845548 (pred)       7.969999999999999 (actual)
Steering angle: 6.362882141152465 (pred)       7.559999999999999 (actual)
Steering angle: 6.035482999703428 (pred)       7.06 (actual)
Steering angle: 6.13392224734259 (pred) 6.25 (actual)
Steering angle: 6.141828618193703 (pred)       5.340000000000001 (actual)
Steering angle: 5.562279810042128 (pred)       4.64 (actual)
Steering angle: 5.720418326121787 (pred)       4.13 (actual)
Steering angle: 5.677702323052527 (pred)       3.7300000000000004 (actual)
Steering angle: 5.782916691461519 (pred)       3.23 (actual)
Steering angle: 5.390022439174406 (pred)       2.7200000000000006 (actual)
Steering angle: 5.171392352710529 (pred)       2.32 (actual)
Steering angle: 5.062971210486216 (pred)       2.02 (actual)
Steering angle: 5.058990490860568 (pred)       1.41 (actual)
Steering angle: 5.193128575970449 (pred)       0.81 (actual)
```

Conclusions:

1 - We have given images and thier corrosponding steering angle in the dataset.

2 - Splitted the data into train & test with 7:3 ratio.

3 - Use the rmsprop optimizer with 1e-4 learning rate.

4 - Use the tanh function to predict the steering angle.

5 - Trained the model till 30 epochsa& saved it to model.ckpt

6 - The ouput was not that great because the hyperparameters of the model are not tuned.

7 - Got the loss of 0.08 but there is a lot of scope for improvement.