In [3]:

```
import numpy as np
import scipy.misc
import random
```

In [0]:

```
from google.colab import drive
drive.mount('/content/gdrive')
%cd /content/gdrive/My\ Drive/AAIC/SelfDrivingCar
```

```
Drive already mounted at /content/gdrive; to attempt to forcibl
y remount, call drive.mount("/content/gdrive", force_remount=Tr
ue).
/content/gdrive/My Drive/AAIC/SelfDrivingCar
```

In [0]:

```
import imageio
from PIL import Image
import csv
```

In [1]:

```
from matplotlib import pyplot as plt
%matplotlib inline
```

In [0]:

```
import os
len(os.listdir('Autopilot-Data/driving_dataset/'))
```

Out[5]:

```
45570
```

In [0]:

```
xs = []
ys = []

train_batch_pointer = 0
val_batch_pointer = 0

#read data.txt
with open("Autopilot-Data/driving_dataset/data.txt") as f:
    for line in f:
        xs.append("Autopilot-Data/driving_dataset/" + line.split()[0])
        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):
      image_read = Image.open(train_xs[(train_batch_pointer + i) % num_train_i
      width, height = image_read.size
      image_np = np.array(image_read.crop((0, height-150, width, height)).resi

      x_out.append(image_np)
      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):
      image_read = Image.open(val_xs[(val_batch_pointer + i) % num_val_images]
      width, height = image_read.size
```

```
        image_np = np.array(image_read.crop((0, height-150, width, height)).resi

        x_out.append(image_np)
        y_out.append([val_ys[(val_batch_pointer + i) % num_val_images]])
    val_batch_pointer += batch_size
    return x_out, y_out
```

In [0]:

```
print(num_images)
print(num_train_images)
print(num_val_images)
```

```
45406
31784
13621
```

In [0]:

```
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.subtract(tf.sigmoid(tf.matmul(h_fc4_drop, W_fc5) + b_fc5),
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x.
We recommend you upgrade (https://www.tensorflow.org/guide/migrate)

now or ensure your notebook will continue to use TensorFlow 1.x via the `%tensorflow_version 1.x` magic: more info (https://colab.research.google.com/notebooks/tensorflow_version.ipynb).

```
WARNING:tensorflow:From <ipython-input-8-6f032eeddfac>:58: call
ing dropout (from tensorflow.python.ops.nn_ops) with keep_prob
is deprecated and will be removed in a future version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to
`rate = 1 - keep_prob`.
```

I have trained the model before for 20 epochs and lost the output of that training while re-training the model. I am loading the model which is saved after 20 epochs and continue the training for 10 epochs.

In [0]:

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

sess = tf.InteractiveSession()
saver = tf.train.Saver(write_version = saver_pb2.SaverDef.V1)
saver.restore(sess, "save/model.ckpt")
```

```
INFO:tensorflow:Restoring parameters from save/model.ckpt
```

In [0]:

```
L2NormConst = 0.0008

train_vars = tf.trainable_variables()

loss = tf.reduce_mean(tf.square(tf.subtract(y_, y))) + tf.add_n([tf.nn.l2_loss
optimizer = tf.train.AdamOptimizer(1e-4)
train_step = optimizer.minimize(loss)
sess.run(tf.variables_initializer(optimizer.variables()))
```

In [0]:

```
epochs = 30
batch_size = 100

xs, ys = LoadValBatch(batch_size)
loss_value = loss.eval(session=sess, feed_dict={x: xs, y_: ys, keep_prob: 0.5}
print(loss_value)
```

```
0.4121355
```

In [12]:

```
LOGDIR = './save'

tf.summary.scalar("loss", loss)
merged_summary_op =  tf.summary.merge_all()

logs_path = './logs'
summary_writer = tf.summary.FileWriter(logs_path, graph=tf.get_default_graph()

epochs = 10
batch_size = 100

for epoch in range(epochs):
  for i in range(int(num_images/batch_size)):
    xs, ys = LoadTrainBatch(batch_size)
    train_step.run(feed_dict={x: xs, y_: ys, keep_prob: 0.5})
    if i % 10 == 0:
      xs, ys = LoadValBatch(batch_size)
      loss_value = loss.eval(feed_dict={x: xs, y_: ys, keep_prob: 0.5})
      print("Epoch: %d, Step: %d, Loss: %g" % (epoch, epoch * batch_size + i,

    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)
```

```
Model saved in file: ./save/model.ckpt
Epoch: 7, Step: 700, Loss: 0.0970607
WARNING:tensorflow:**********************************************
*************
WARNING:tensorflow:TensorFlow's V1 checkpoint format has been
deprecated.
WARNING:tensorflow:Consider switching to the more efficient V
2 format:
WARNING:tensorflow:   `tf.train.Saver(write_version=tf.train.
SaverDef.V2)`
WARNING:tensorflow:now on by default.
WARNING:tensorflow:**********************************************
*************
Epoch: 7, Step: 710, Loss: 0.14368
Epoch: 7, Step: 720, Loss: 0.509449
Epoch: 7, Step: 730, Loss: 0.377441
Epoch: 7, Step: 740, Loss: 0.12328
Epoch: 7, Step: 750, Loss: 0.195109
Epoch: 7, Step: 760, Loss: 0.0956952
Epoch: 7, Step: 770, Loss: 0.0962533
```

I am calculating predicted steering angles here and storing them to use later in opencv which will be run on desktop python.

In [0]:

```
from tqdm import tqdm
```

In [14]:

```
out_file = open('test-predictions.csv', 'w')
csv_writer = csv.writer(out_file)
csv_writer.writerow(['fileID', 'steering_angle'])
```

Out[14]:

```
23
```

In [0]:

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

smoothed_angle = 0
angle_ouputs = []

ind = 0

for img_path in val_xs:

    image_read = Image.open(img_path)
    width, height = image_read.size
    image_np = np.array(image_read.crop((0, height-150, width, height)).resize

    degrees = y.eval(feed_dict={x: [image_np], keep_prob: 0.5})[0][0] * 180 /

    print(f'{ind}/{num_val_images} => Actual: {val_ys[ind]*180/scipy.pi}, Pred
    angle_ouputs.append(degrees)
    csv_writer.writerow([img_path, degrees])
    ind+=1
out_file.close()
```

```
11115/13621 => Actual: 1.11, Predicted: 11.434003047978976
11116/13621 => Actual: 0.91, Predicted: 8.765700856254284
11117/13621 => Actual: 0.71, Predicted: 2.9432856077094045
11118/13621 => Actual: 0.5, Predicted: 13.013067652005054
11119/13621 => Actual: 0.5, Predicted: 11.978744785233342
11120/13621 => Actual: 0.3, Predicted: 10.110619745343156
11121/13621 => Actual: 0.2, Predicted: 4.706027658895466
11122/13621 => Actual: 0.0, Predicted: 5.739305506724165
11123/13621 => Actual: -0.4, Predicted: 9.726216698854838
11124/13621 => Actual: -0.81, Predicted: 6.120757911491037
11125/13621 => Actual: -1.51, Predicted: 2.4321074200364805
11126/13621 => Actual: -2.42, Predicted: 7.967040006415523
11127/13621 => Actual: -3.4300000000000006, Predicted: 4.5718
96403974755
11128/13621 => Actual: -4.13, Predicted: 1.694795329322774
11129/13621 => Actual: -4.94, Predicted: -0.5896160801013507
11130/13621 => Actual: -5.139999999999999, Predicted: 0.99114
92410280603
11131/13621 => Actual: -5.45, Predicted: 6.986996652977904
```

Conclusion:

Conclusion:

- **I have tried a lot of models and pick the model that did best which is above model. Even though the log-loss is not that good, the video result is good. I am listing some of the observations below.**
- **I have tried linear but couldnt achieve good results. The steering angle is constant.**
- **So I took sigmoid function as the shape of graph is slightly similar to arcTan but even after some trails I didnt get good results. I got constant output near 0 degrees.**
- **I have tried several combinations of sigmoid and linear and finally took 6(sigmoid-0.5) as my final activation function. This is because if we draw both plots we get almost similar graphs. (Will plot at end of the notebook).**
- **Even with this model I didnt get good results after trying with different dropouts.**
- **At last I reduced the normalization coefficient to 0.0008 as I thought my model is underfitting and kept the Adam learning rate back to 1e-4 these values worked fine for me and gave better results.**

I trained the model and calculated predicted steering angles here and stored them to use later in opencv which will be run on desktop python. I will attach .py file as well to see the opencv code.

Video Observations:

- **There is lot of sudden movements (jerks) in the steering. And there is no proper continuity in the angles.**
- **The right angles seems to be amplified a bit and left angles seems to be weakened a bit.**
- **First few seconds of the video is not good showing extreme right turn even when it is not good. But later part of video is quite good.**
- **And most of the time the steering angle's polarity is correct (polarity: left or right) even though the amplitude of the turn is incorrect.**

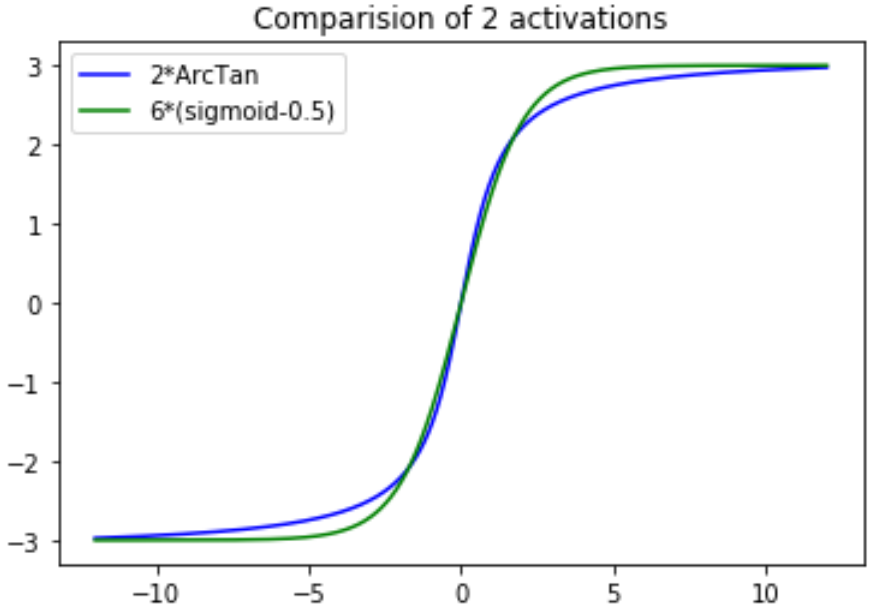
In [4]:

```
import math

def sigmoid(x):
  return 1 / (1 + math.exp(-x))

arctan_x = []
sigmoid_x = []
x_s = np.arange(-12, 12, 0.01)
for x in x_s:
  arctan_x.append(2*math.atan(x))
  sigmoid_x.append(6*(sigmoid(x)-0.5))

plt.plot(list(x_s), arctan_x, c='b', label='2*ArcTan')
plt.plot(list(x_s), sigmoid_x, c='g', label='6*(sigmoid-0.5)')
plt.legend()
plt.title("Comparision of 2 activations")
plt.show()
```



In [0]: