```
!git clone https://github.com/rslim087a/track
```

```
Cloning into 'track'...
remote: Enumerating objects: 12163, done.ote: Total 12163 (delta 0),
reused 0 (delta 0), pack-reused 12163
```

```
!ls track
```

```
driving_log.csv  IMG
```

```
import os
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
import keras
from keras.models import Sequential
from keras.optimizers import Adam
from keras.layers import Convolution2D, MaxPooling2D, Dropout,
Flatten, Dense
from sklearn.utils import shuffle
from sklearn.model_selection import train_test_split
from imgaug import augmenters as iaa
import cv2
import pandas as pd
import ntpath
import random
```

```
datadir = 'track'
columns = ['center', 'left', 'right', 'steering', 'throttle',
'reverse', 'speed']
data = pd.read_csv(os.path.join(datadir, 'driving_log.csv'), names =
columns)
pd.set_option('display.max_colwidth', -1)
data.head()
```

```
<ipython-input-4-8dde8c7f6a42>:4: FutureWarning: Passing a negative
integer is deprecated in version 1.0 and will not be supported in
future version. Instead, use None to not limit the column width.
  pd.set_option('display.max_colwidth', -1)
```

```
center  \
0  C:\Users\Amer\Desktop\new_track\IMG\
center_2018_07_16_17_11_43_382.jpg
1  C:\Users\Amer\Desktop\new_track\IMG\
center_2018_07_16_17_11_43_670.jpg
2  C:\Users\Amer\Desktop\new_track\IMG\
center_2018_07_16_17_11_43_724.jpg
3  C:\Users\Amer\Desktop\new_track\IMG\
center_2018_07_16_17_11_43_792.jpg
4  C:\Users\Amer\Desktop\new_track\IMG\
```

```
center_2018_07_16_17_11_43_860.jpg


left  \
0  C:\Users\Amer\Desktop\new_track\IMG\
left_2018_07_16_17_11_43_382.jpg
1  C:\Users\Amer\Desktop\new_track\IMG\
left_2018_07_16_17_11_43_670.jpg
2  C:\Users\Amer\Desktop\new_track\IMG\
left_2018_07_16_17_11_43_724.jpg
3  C:\Users\Amer\Desktop\new_track\IMG\
left_2018_07_16_17_11_43_792.jpg
4  C:\Users\Amer\Desktop\new_track\IMG\
left_2018_07_16_17_11_43_860.jpg


right  \
0  C:\Users\Amer\Desktop\new_track\IMG\
right_2018_07_16_17_11_43_382.jpg
1  C:\Users\Amer\Desktop\new_track\IMG\
right_2018_07_16_17_11_43_670.jpg
2  C:\Users\Amer\Desktop\new_track\IMG\
right_2018_07_16_17_11_43_724.jpg
3  C:\Users\Amer\Desktop\new_track\IMG\
right_2018_07_16_17_11_43_792.jpg
4  C:\Users\Amer\Desktop\new_track\IMG\
right_2018_07_16_17_11_43_860.jpg

   steering  throttle  reverse     speed
0  0.0       0.0       0.0      0.649786
1  0.0       0.0       0.0      0.627942
2  0.0       0.0       0.0      0.622910
3  0.0       0.0       0.0      0.619162
4  0.0       0.0       0.0      0.615438
```

```
def path_leaf(path):
  head, tail = ntpath.split(path)
  return tail
data['center'] = data['center'].apply(path_leaf)
data['left'] = data['left'].apply(path_leaf)
data['right'] = data['right'].apply(path_leaf)
data.head()
```

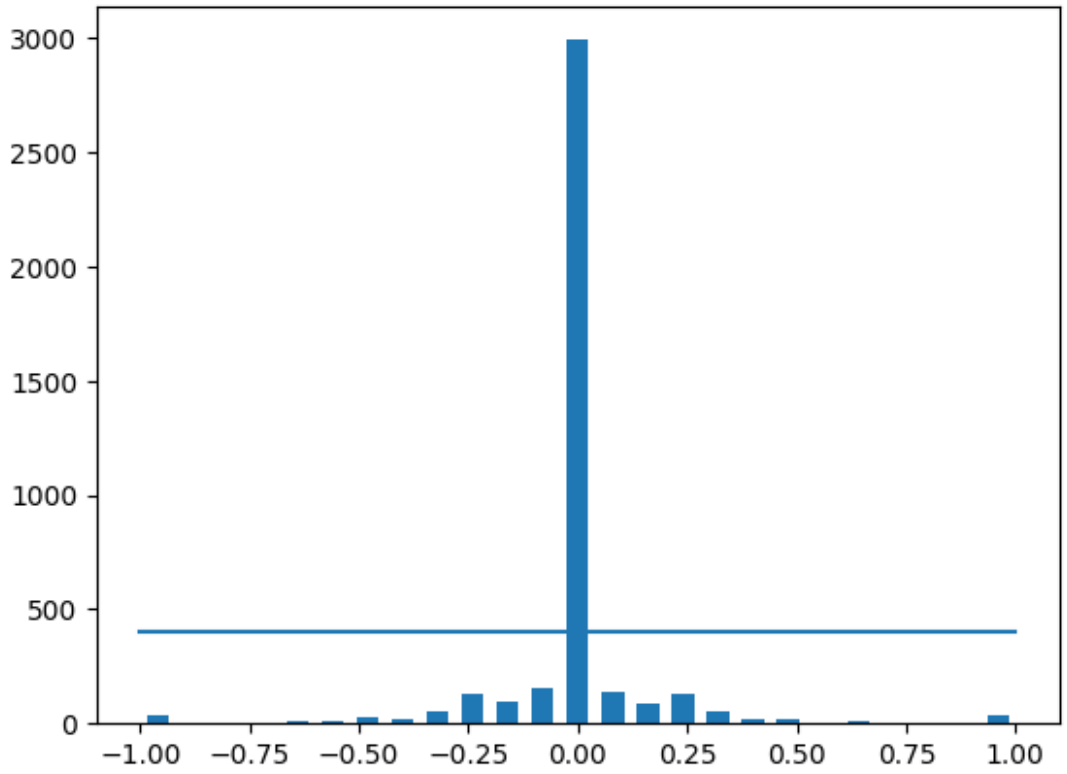
```
                                center
left  \
0  center_2018_07_16_17_11_43_382.jpg
left_2018_07_16_17_11_43_382.jpg
1  center_2018_07_16_17_11_43_670.jpg
left_2018_07_16_17_11_43_670.jpg
2  center_2018_07_16_17_11_43_724.jpg
```

```
left_2018_07_16_17_11_43_724.jpg
3  center_2018_07_16_17_11_43_792.jpg
left_2018_07_16_17_11_43_792.jpg
4  center_2018_07_16_17_11_43_860.jpg
left_2018_07_16_17_11_43_860.jpg
```

```
                                right  steering  throttle  reverse
speed
0  right_2018_07_16_17_11_43_382.jpg  0.0       0.0       0.0
0.649786
1  right_2018_07_16_17_11_43_670.jpg  0.0       0.0       0.0
0.627942
2  right_2018_07_16_17_11_43_724.jpg  0.0       0.0       0.0
0.622910
3  right_2018_07_16_17_11_43_792.jpg  0.0       0.0       0.0
0.619162
4  right_2018_07_16_17_11_43_860.jpg  0.0       0.0       0.0
0.615438
```

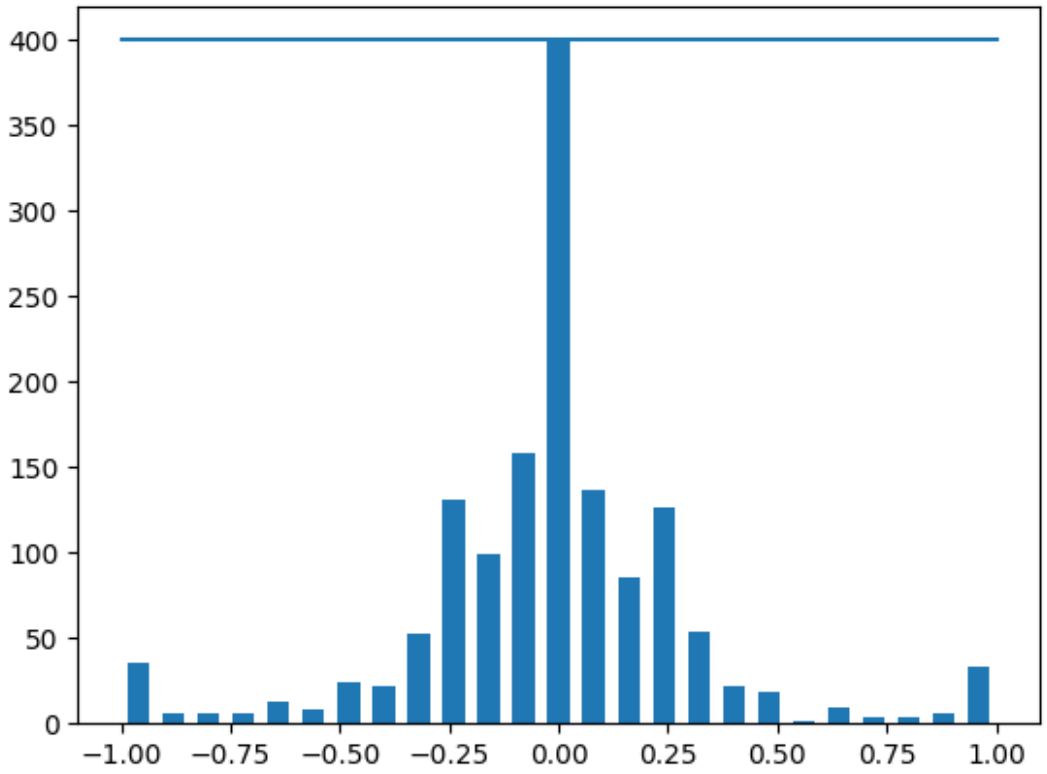
```
num_bins = 25
samples_per_bin = 400
hist, bins = np.histogram(data['steering'], num_bins)
center = (bins[:-1]+ bins[1:]) * 0.5
plt.bar(center, hist, width=0.05)
plt.plot((np.min(data['steering']), np.max(data['steering'])),
(samples_per_bin, samples_per_bin))
```

```
[<matplotlib.lines.Line2D at 0x7ad5d24ae350>]
```




```
print('total data:', len(data))
remove_list = []
for j in range(num_bins):
  list_ = []
  for i in range(len(data['steering'])):
    if data['steering'][i] >= bins[j] and data['steering'][i] <=
bins[j+1]:
      list_.append(i)
  list_ = shuffle(list_)
  list_ = list_[samples_per_bin:]
  remove_list.extend(list_)

print('removed:', len(remove_list))
data.drop(data.index[remove_list], inplace=True)
print('remaining:', len(data))

hist, _ = np.histogram(data['steering'], (num_bins))
plt.bar(center, hist, width=0.05)
plt.plot((np.min(data['steering']), np.max(data['steering'])),
(samples_per_bin, samples_per_bin))
```

```
total data: 4053
removed: 2590
remaining: 1463

[<matplotlib.lines.Line2D at 0x7ad5d23e5450>]
```




```
print(data.iloc[1])
def load_img_steering(datadir, df):
  image_path = []
  steering = []
  for i in range(len(data)):
    indexed_data = data.iloc[i]
    center, left, right = indexed_data[0], indexed_data[1],
indexed_data[2]
    image_path.append(os.path.join(datadir, center.strip()))
    steering.append(float(indexed_data[3]))
    # left image append
    image_path.append(os.path.join(datadir,left.strip()))
    steering.append(float(indexed_data[3])+0.15)
    # right image append
    image_path.append(os.path.join(datadir,right.strip()))
    steering.append(float(indexed_data[3])-0.15)
  image_paths = np.asarray(image_path)
  steerings = np.asarray(steering)
  return image_paths, steerings

image_paths, steerings = load_img_steering(datadir + '/IMG', data)
```

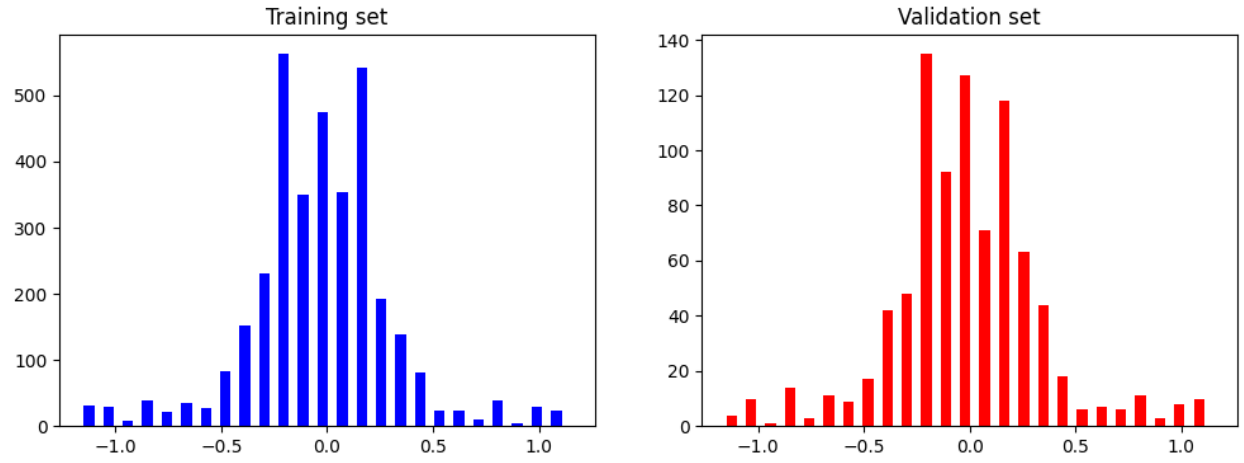
```
center      center_2018_07_16_17_11_44_413.jpg
left        left_2018_07_16_17_11_44_413.jpg
right       right_2018_07_16_17_11_44_413.jpg
```

```
steering   -0.05
throttle    0.642727
reverse     0.0
speed       1.434013
Name: 12, dtype: object
```

```
X_train, X_valid, y_train, y_valid = train_test_split(image_paths,
steerings, test_size=0.2, random_state=6)
print('Training Samples: {}\nValid Samples: {}'.format(len(X_train),
len(X_valid)))
fig, axes = plt.subplots(1, 2, figsize=(12, 4))
axes[0].hist(y_train, bins=num_bins, width=0.05, color='blue')
axes[0].set_title('Training set')
axes[1].hist(y_valid, bins=num_bins, width=0.05, color='red')
axes[1].set_title('Validation set')
```

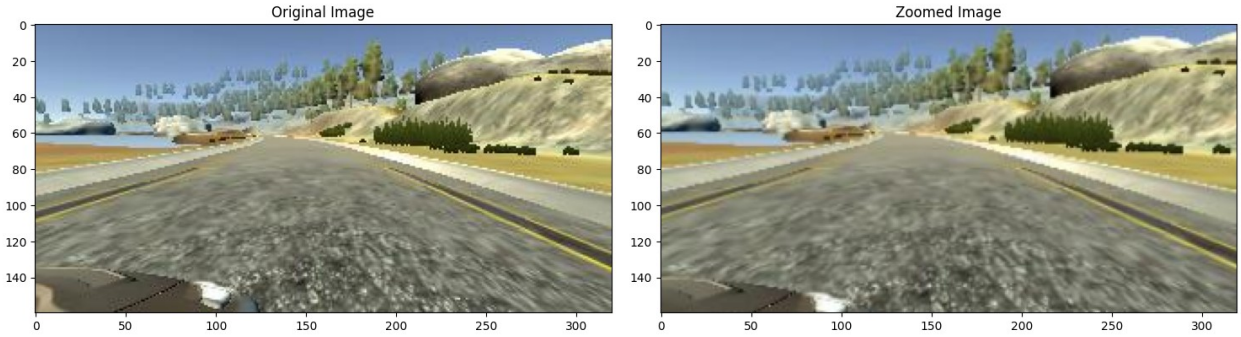
```
Training Samples: 3511
Valid Samples: 878
```

```
Text(0.5, 1.0, 'Validation set')
```

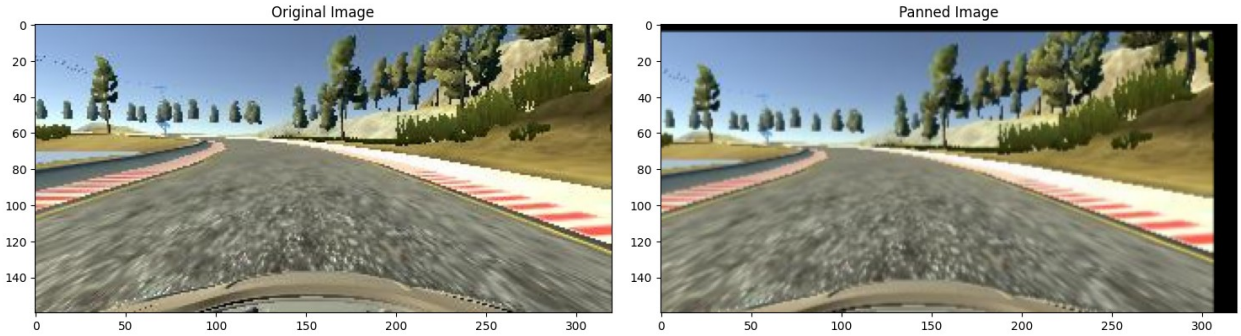



```
def zoom(image):
  zoom = iaa.Affine(scale=(1, 1.3))
  image = zoom.augment_image(image)
  return image

image = image_paths[random.randint(0, 1000)]
original_image = mpimg.imread(image)
zoomed_image = zoom(original_image)

fig, axs = plt.subplots(1, 2, figsize=(15, 10))
fig.tight_layout()

axs[0].imshow(original_image)
axs[0].set_title('Original Image')
```

```
axs[1].imshow(zoomed_image)
axs[1].set_title('Zoomed Image')

Text(0.5, 1.0, 'Zoomed Image')
```

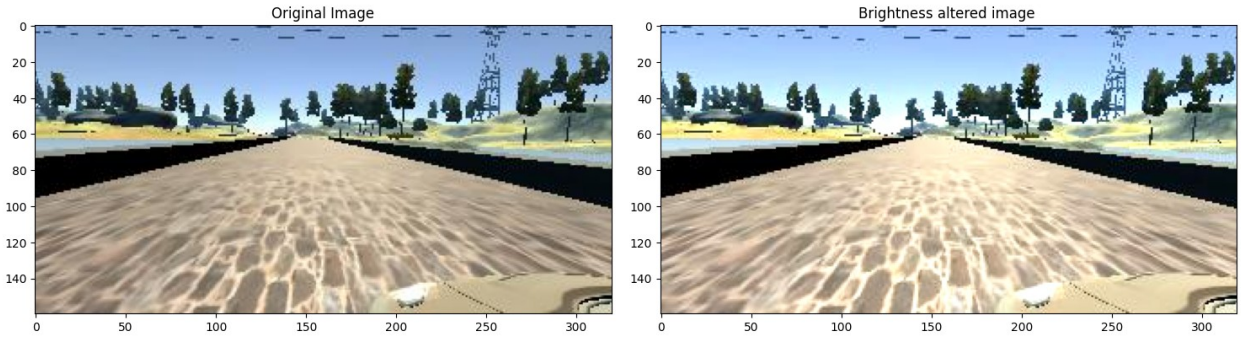



```
def pan(image):
  pan = iaa.Affine(translate_percent= {"x" : (-0.1, 0.1), "y": (-0.1,
0.1)})
  image = pan.augment_image(image)
  return image

image = image_paths[random.randint(0, 1000)]
original_image = mpimg.imread(image)
panned_image = pan(original_image)
fig, axs = plt.subplots(1, 2, figsize=(15, 10))
fig.tight_layout()

axs[0].imshow(original_image)
axs[0].set_title('Original Image')

axs[1].imshow(panned_image)
axs[1].set_title('Panned Image')

Text(0.5, 1.0, 'Panned Image')
```




```
def img_random_brightness(image):
    brightness = iaa.Multiply((0.2, 1.2))
```

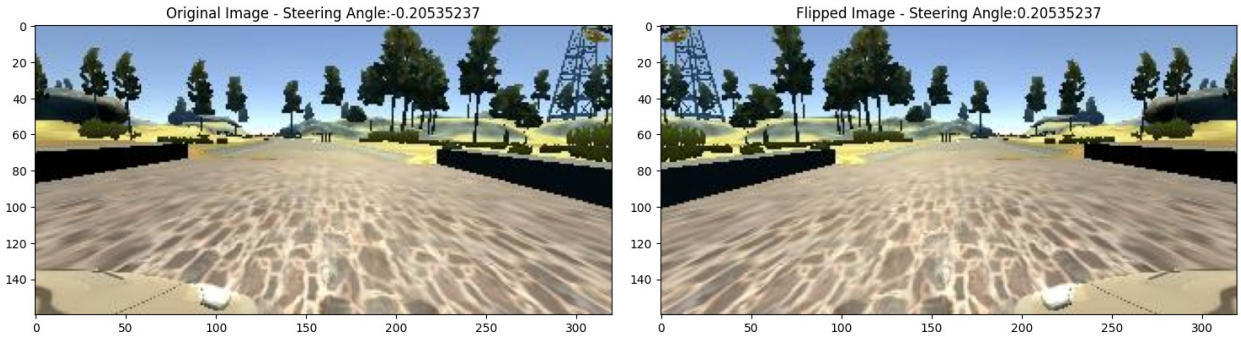
```
    image = brightness.augment_image(image)
    return image

image = image_paths[random.randint(0, 1000)]
original_image = mpimg.imread(image)
brightness_altered_image = img_random_brightness(original_image)

fig, axs = plt.subplots(1, 2, figsize=(15, 10))
fig.tight_layout()

axs[0].imshow(original_image)
axs[0].set_title('Original Image')

axs[1].imshow(brightness_altered_image)
axs[1].set_title('Brightness altered image ')

Text(0.5, 1.0, 'Brightness altered image ')
```



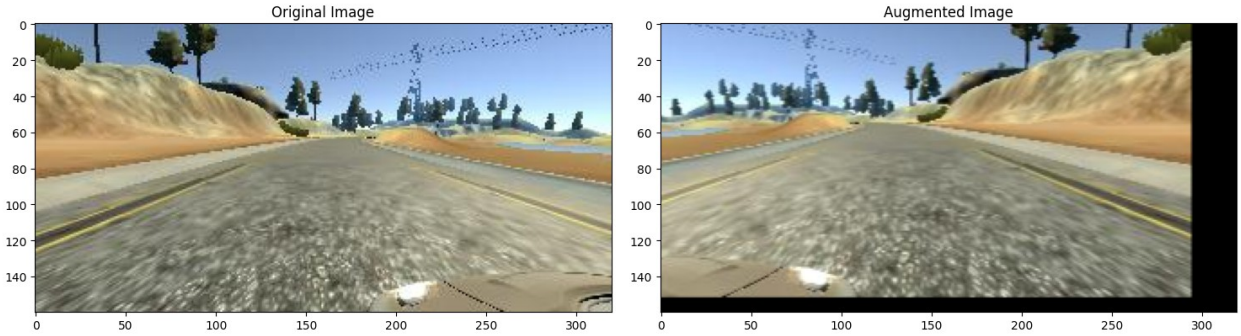

```
def img_random_flip(image, steering_angle):
    image = cv2.flip(image,1)
    steering_angle = -steering_angle
    return image, steering_angle

random_index = random.randint(0, 1000)
image = image_paths[random_index]
steering_angle = steerings[random_index]


original_image = mpimg.imread(image)
flipped_image, flipped_steering_angle =
img_random_flip(original_image, steering_angle)

fig, axs = plt.subplots(1, 2, figsize=(15, 10))
fig.tight_layout()

axs[0].imshow(original_image)
axs[0].set_title('Original Image - ' + 'Steering Angle:' +
str(steering_angle))
```

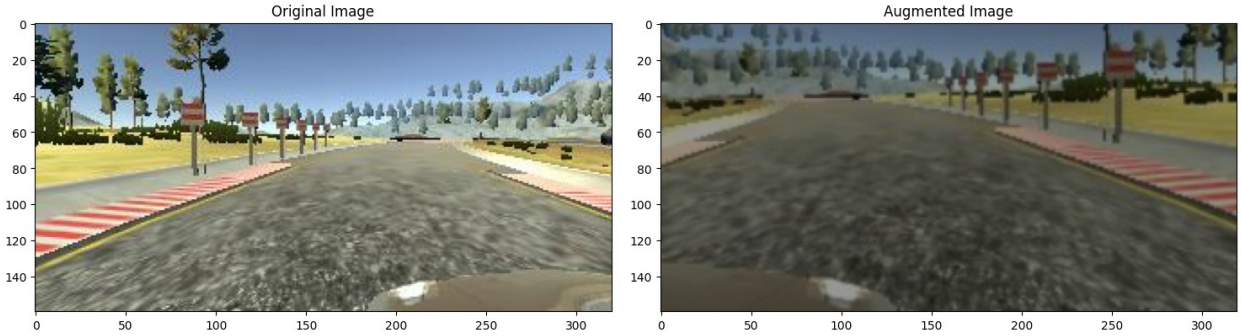
```
axs[1].imshow(flipped_image)
axs[1].set_title('Flipped Image - ' + 'Steering Angle:' +
str(flipped_steering_angle))
```

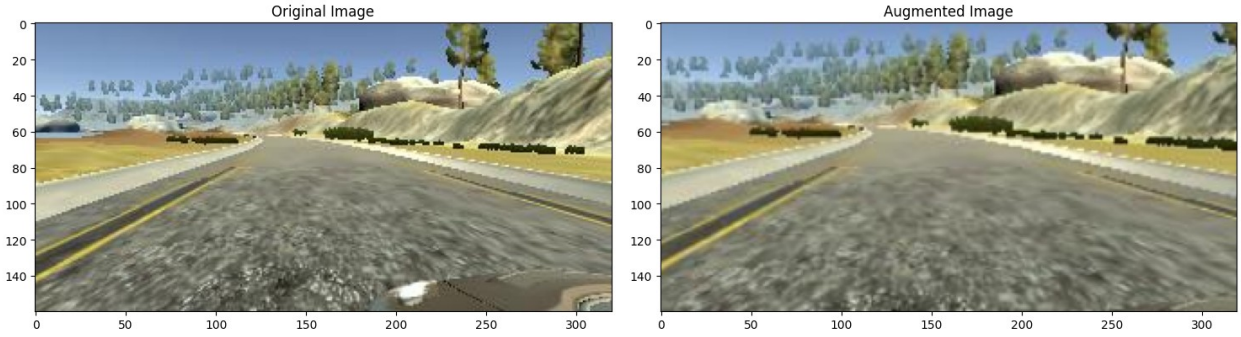
```
Text(0.5, 1.0, 'Flipped Image - Steering Angle:0.20535237')
```

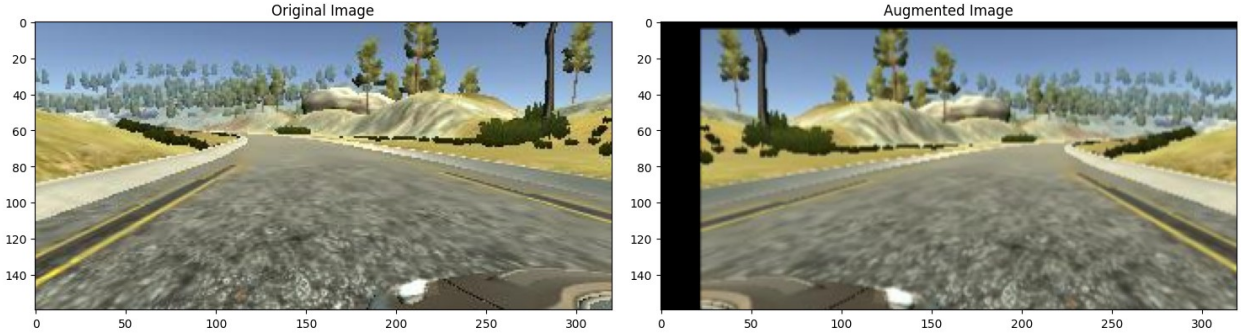



```
def random_augment(image, steering_angle):
    image = mpimg.imread(image)
    if np.random.rand() < 0.5:
      image = pan(image)
    if np.random.rand() < 0.5:
      image = zoom(image)
    if np.random.rand() < 0.5:
      image = img_random_brightness(image)
    if np.random.rand() < 0.5:
      image, steering_angle = img_random_flip(image, steering_angle)

    return image, steering_angle

ncol = 2
nrow = 10

fig, axs = plt.subplots(nrow, ncol, figsize=(15, 50))
fig.tight_layout()

for i in range(10):
  randnum = random.randint(0, len(image_paths) - 1)
  random_image = image_paths[randnum]
  random_steering = steerings[randnum]

  original_image = mpimg.imread(random_image)
  augmented_image, steering = random_augment(random_image,
random_steering)

  axs[i][0].imshow(original_image)
  axs[i][0].set_title("Original Image")

  axs[i][1].imshow(augmented_image)
  axs[i][1].set_title("Augmented Image")
```


Original Image
Augmented Image

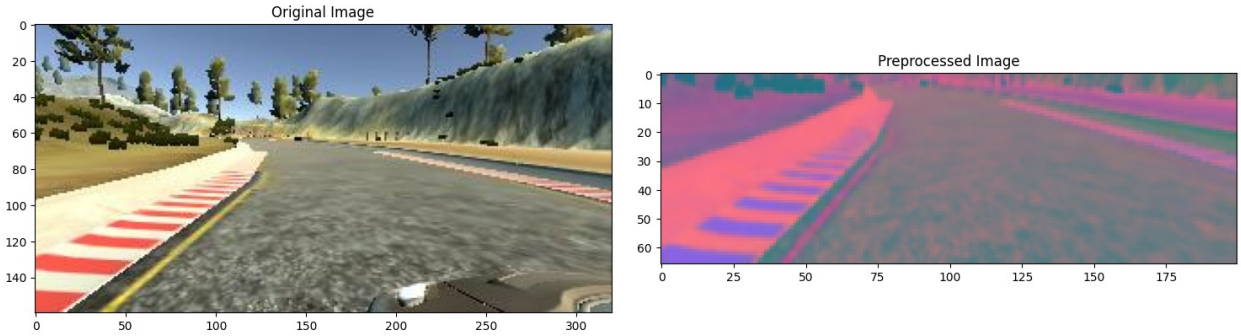

Original Image
Augmented Image


Original Image
Augmented Image


Original Image
Augmented Image


Original Image
Augmented Image

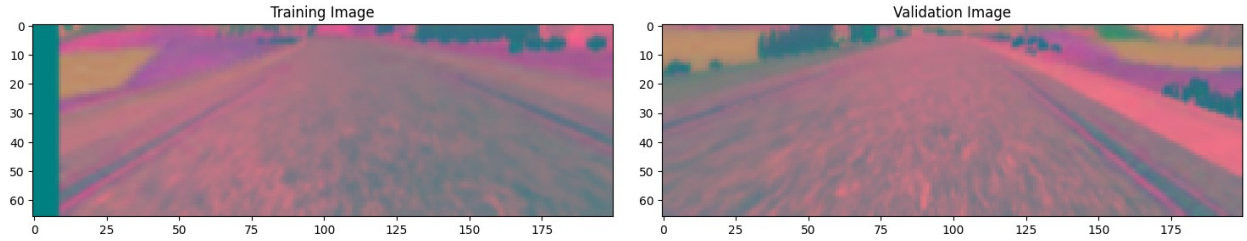
```
def img_preprocess(img):
    img = img[60:135,:,:]
    img = cv2.cvtColor(img, cv2.COLOR_RGB2YUV)
    img = cv2.GaussianBlur(img,  (3, 3), 0)
    img = cv2.resize(img, (200, 66))
    img = img/255
    return img

image = image_paths[100]
original_image = mpimg.imread(image)
preprocessed_image = img_preprocess(original_image)

fig, axs = plt.subplots(1, 2, figsize=(15, 10))
fig.tight_layout()
axs[0].imshow(original_image)
axs[0].set_title('Original Image')
axs[1].imshow(preprocessed_image)
axs[1].set_title('Preprocessed Image')

Text(0.5, 1.0, 'Preprocessed Image')
```




```
def batch_generator(image_paths, steering_ang, batch_size,
istraining):

  while True:
    batch_img = []
    batch_steering = []

    for i in range(batch_size):
      random_index = random.randint(0, len(image_paths) - 1)

      if istraining:
        im, steering = random_augment(image_paths[random_index],
steering_ang[random_index])

      else:
        im = mpimg.imread(image_paths[random_index])
        steering = steering_ang[random_index]
```

```
      im = img_preprocess(im)
      batch_img.append(im)
      batch_steering.append(steering)
    yield (np.asarray(batch_img), np.asarray(batch_steering))

x_train_gen, y_train_gen = next(batch_generator(X_train, y_train, 1,
1))
x_valid_gen, y_valid_gen = next(batch_generator(X_valid, y_valid, 1,
0))

fig, axs = plt.subplots(1, 2, figsize=(15, 10))
fig.tight_layout()

axs[0].imshow(x_train_gen[0])
axs[0].set_title('Training Image')

axs[1].imshow(x_valid_gen[0])
axs[1].set_title('Validation Image')
```

```
Text(0.5, 1.0, 'Validation Image')
```




```
def nvidia_model():
  model = Sequential()
  model.add(Convolution2D(24, (5, 5), strides=(2, 2), input_shape=(66,
200, 3), activation='elu'))
  model.add(Convolution2D(36, (5, 5), strides=(2, 2),
activation='elu'))
  model.add(Convolution2D(48,( 5, 5), strides=(2, 2),
activation='elu'))
  model.add(Convolution2D(64, (3, 3), activation='elu'))

  model.add(Convolution2D(64, (3, 3), activation='elu'))
#   model.add(Dropout(0.5))


  model.add(Flatten())

  model.add(Dense(100, activation = 'elu'))
#   model.add(Dropout(0.5))

  model.add(Dense(50, activation = 'elu'))
#   model.add(Dropout(0.5))
```

```
  model.add(Dense(10, activation = 'elu'))
#   model.add(Dropout(0.5))

  model.add(Dense(1))

  optimizer = Adam(lr=1e-3)
  model.compile(loss='mse', optimizer=optimizer)
  return model

model = nvidia_model()
print(model.summary())
```

```
WARNING:absl:`lr` is deprecated in Keras optimizer, please use
`learning_rate` or use the legacy optimizer,
e.g.,tf.keras.optimizers.legacy.Adam.

Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_5 (Conv2D)           (None, 31, 98, 24)        1824

 conv2d_6 (Conv2D)           (None, 14, 47, 36)        21636

 conv2d_7 (Conv2D)           (None, 5, 22, 48)         43248

 conv2d_8 (Conv2D)           (None, 3, 20, 64)         27712

 conv2d_9 (Conv2D)           (None, 1, 18, 64)         36928

 flatten (Flatten)           (None, 1152)              0

 dense (Dense)               (None, 100)               115300

 dense_1 (Dense)             (None, 50)                5050

 dense_2 (Dense)             (None, 10)                510

 dense_3 (Dense)             (None, 1)                 11

=================================================================
Total params: 252219 (985.23 KB)
Trainable params: 252219 (985.23 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
None
```

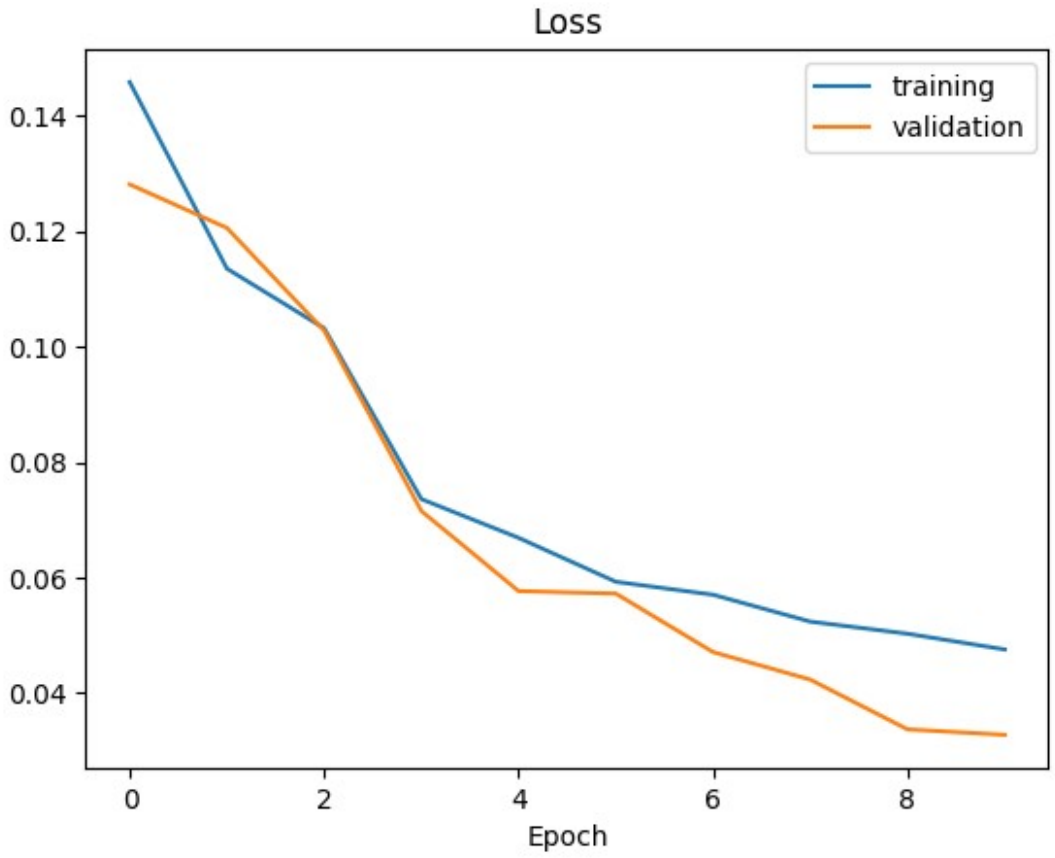
```
history = model.fit_generator(batch_generator(X_train, y_train, 100,
1),
```

```
                                    steps_per_epoch=300,
                                    epochs=10,

validation_data=batch_generator(X_valid, y_valid, 100, 0),
                                    validation_steps=200,
                                    verbose=1,
                                    shuffle = 1)
```

```
<ipython-input-33-1380e7fdc075>:1: UserWarning: `Model.fit_generator` is deprecated and will be removed in a future version. Please use `Model.fit`, which supports generators.
  history = model.fit_generator(batch_generator(X_train, y_train, 100, 1),

Epoch 1/10
300/300 [==============================] - 371s 1s/step - loss: 0.1458 - val_loss: 0.1281
Epoch 2/10
300/300 [==============================] - 332s 1s/step - loss: 0.1135 - val_loss: 0.1206
Epoch 3/10
300/300 [==============================] - 340s 1s/step - loss: 0.1032 - val_loss: 0.1028
Epoch 4/10
300/300 [==============================] - 337s 1s/step - loss: 0.0736 - val_loss: 0.0715
Epoch 5/10
300/300 [==============================] - 337s 1s/step - loss: 0.0669 - val_loss: 0.0576
Epoch 6/10
300/300 [==============================] - 320s 1s/step - loss: 0.0593 - val_loss: 0.0572
Epoch 7/10
300/300 [==============================] - 330s 1s/step - loss: 0.0570 - val_loss: 0.0471
Epoch 8/10
300/300 [==============================] - 356s 1s/step - loss: 0.0524 - val_loss: 0.0423
Epoch 9/10
300/300 [==============================] - 315s 1s/step - loss: 0.0503 - val_loss: 0.0337
Epoch 10/10
300/300 [==============================] - 339s 1s/step - loss: 0.0475 - val_loss: 0.0327
```

```
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.legend(['training', 'validation'])
plt.title('Loss')
plt.xlabel('Epoch')
```

```
Text(0.5, 0, 'Epoch')
```




```
model.save('model.h5')
```

```
/usr/local/lib/python3.10/dist-packages/keras/src/engine/
training.py:3079: UserWarning: You are saving your model as an HDF5
file via `model.save()`. This file format is considered legacy. We
recommend using instead the native Keras format, e.g.
`model.save('my_model.keras')`.
  saving_api.save_model(
```

```
from google.colab import files
files.download('model.h5')
```

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

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