Low Light Enhancement using Deep Retinex Decomposition

Images have a wide range of applications in the field of engineering like in medical field, remote sensing, transmission and encoding, machine vision, robotics, pattern recognition, etc.

In some cases, the images captured by cameras contains blur, noise and low lightness in it. This causes difficulty to viewer in extracting the information from it.There can be many causes of this problem like low light environment, poor performance of the equipment, inappropriate configurations of the equipment.

The objective of this case study is to build a model(Deep Retinex Decomposition model) using deep learning techniques like CNN, Encoder-decoder that will learn from the existing dataset of low and high quality images and will be able to convert any poor quality image given to it into the high quality image.

```
!pip install tensorflow==1.15.0
```

```
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
import time
import os
import random
from PIL import Image
from glob import glob
from tqdm import tqdm
import pickle
```

Exploratory data analysis

https:/ /github.com/weichen582/RetinexNet

The dataset named LOL (LOw Light paired) dataset used for the problem is taken from the above link. It contains 5000 low/normal light images pairs of different kinds such as household appliances, toys, books, garden, food items, playground, clubs, streets etc.

These raw images are resized to 128*128 and converted to Portable Network Graphics format.

Below figure shows the subset of these images.


```
def load_images(file):
    im = Image.open(file)
    newsize = (128, 128)
    im = im.resize(newsize)
    return np.array(im, dtype="float32") / 255.0
```

Training data

```
train_low_data_names = glob('/content/drive/MyDrive/Case_study_2/data_2/low/*.png')
train_low_data_names.sort()
train_high_data_names = glob('/content/drive/MyDrive/Case_study_2/data_2/high/*.png')
train_high_data_names.sort()
assert len(train_low_data_names) == len(train_high_data_names)

train_low_data = []
train_high_data = []

for idx in tqdm(range(5000)):
#for idx in tqdm(range(len(train_low_data_names))):
    low_im = load_images(train_low_data_names[idx])
    train_low_data.append(low_im)
    high_im = load_images(train_high_data_names[idx])
    train_high_data.append(high_im)
```

```
100%|██████████| 5000/5000 [00:20<00:00, 248.60it/s]
```

```
print('Number of training data points: %d' % len(train_low_data))
```

```
Number of training data points: 5000
```

Testing data

```
eval_low_data = []

eval_low_data_name = glob('/content/drive/MyDrive/Case_study_2/data/eval15/low/*.png')

for idx in tqdm(range(len(eval_low_data_name))):
    eval_low_im = load_images(eval_low_data_name[idx])
    eval_low_data.append(eval_low_im)
```

```
 100%|██████████| 15/15 [00:00<00:00, 99.80it/s]
```

```
eval_high_data = []

eval_high_data_name = glob('/content/drive/MyDrive/Case_study_2/data/eval15/high/*.png')

for idx in tqdm(range(len(eval_high_data_name))):
    eval_high_im = load_images(eval_high_data_name[idx])
    eval_high_data.append(eval_high_im)
```

```
 100%|██████████| 15/15 [00:00<00:00, 95.30it/s]
```

```
print('Number of testing data points: %d' % len(eval_low_data_name))
```

```
Number of testing data points: 15
```

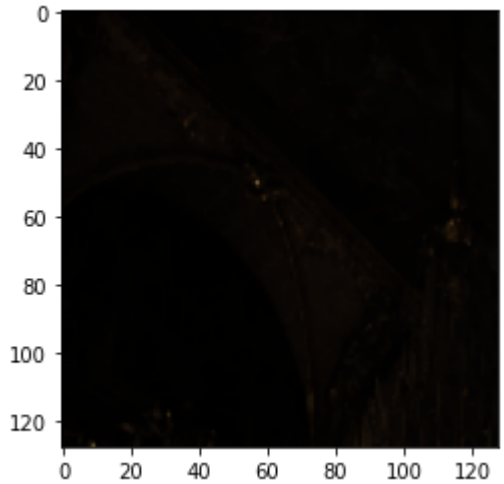
Sample low light and high light image

```
low_img = train_low_data[200]
print("Shape of the image", low_img.shape)
```

```
Shape of the image (128, 128, 3)
```

```
plt.imshow(low_img[ : , : , :])
```

```
<matplotlib.image.AxesImage at 0x7fb535c1f390>
```

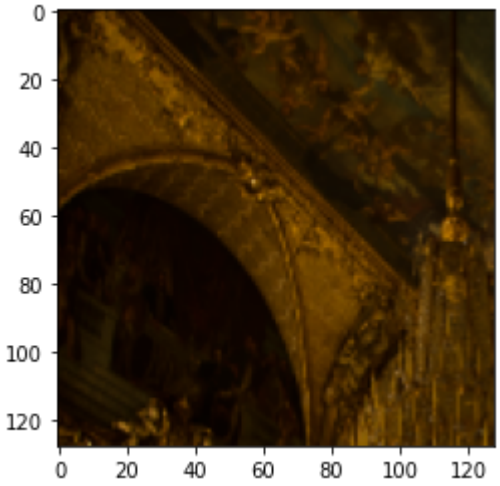


```
high_img = train_high_data[200]
print("Shape of the image", high_img.shape)
```

```
Shape of the image (128, 128, 3)
```

```
plt.imshow(high_img[ : , : , :])
```

```
<matplotlib.image.AxesImage at 0x7fb535706a50>
```



Observations from EDA

Dataset for training contains 5000 images, each of one is an RGB image with size 128×128×3.

Dataset for testing contains 15 images, each of one is an RGB image with size 128×128×3.

For each image, we have a pair of low and high light image.

Decomposition

```
print(tf.__version__)
```

```
1.15.0
```

```
def concat(layers):
    return tf.concat(layers, axis=3)
```

```
def DecomNet(input_im, layer_num, channel=64, kernel_size=3):
    input_max = tf.reduce_max(input_im, axis=3, keepdims=True)
    input_im = concat([input_max, input_im])
```

```
        with tf.variable_scope('DecomNet', reuse=tf.AUTO_REUSE):
            conv = tf.layers.conv2d(input_im, channel, kernel_size * 3, padding='same', activatio
            for idx in range(layer_num):
                conv = tf.layers.conv2d(conv, channel, kernel_size, padding='same', activation=tf
            conv = tf.layers.conv2d(conv, 4, kernel_size, padding='same', activation=None, name='

        R = tf.sigmoid(conv[:,:,:,0:3])
        L = tf.sigmoid(conv[:,:,:,3:4])

        return R, L

    def RelightNet(input_L, input_R, channel=64, kernel_size=3):
        input_im = concat([input_R, input_L])
        with tf.variable_scope('RelightNet', reuse=tf.AUTO_REUSE):
            conv0 = tf.layers.conv2d(input_im, channel, kernel_size, padding='same', activation=N
            conv1 = tf.layers.conv2d(conv0, channel, kernel_size, strides=2, padding='same', acti
            conv2 = tf.layers.conv2d(conv1, channel, kernel_size, strides=2, padding='same', acti
            conv3 = tf.layers.conv2d(conv2, channel, kernel_size, strides=2, padding='same', acti

            up1 = tf.image.resize_nearest_neighbor(conv3, (tf.shape(conv2)[1], tf.shape(conv2)[2]
            deconv1 = tf.layers.conv2d(up1, channel, kernel_size, padding='same', activation=tf.n
            up2 = tf.image.resize_nearest_neighbor(deconv1, (tf.shape(conv1)[1], tf.shape(conv1)[
            deconv2= tf.layers.conv2d(up2, channel, kernel_size, padding='same', activation=tf.nn
            up3 = tf.image.resize_nearest_neighbor(deconv2, (tf.shape(conv0)[1], tf.shape(conv0)[
            deconv3 = tf.layers.conv2d(up3, channel, kernel_size, padding='same', activation=tf.n

            deconv1_resize = tf.image.resize_nearest_neighbor(deconv1, (tf.shape(deconv3)[1], tf.
            deconv2_resize = tf.image.resize_nearest_neighbor(deconv2, (tf.shape(deconv3)[1], tf.
            feature_gather = concat([deconv1_resize, deconv2_resize, deconv3])
            feature_fusion = tf.layers.conv2d(feature_gather, channel, 1, padding='same', activat
            output = tf.layers.conv2d(feature_fusion, 1, 3, padding='same', activation=None)
        return output


    def data_augmentation(image, mode):
        if mode == 0:
            # original
            return image
        elif mode == 1:
            # flip up and down
            return np.flipud(image)
        elif mode == 2:
            # rotate counterwise 90 degree
            return np.rot90(image)
        elif mode == 3:
            # rotate 90 degree and flip up and down
            image = np.rot90(image)
            return np.flipud(image)
        elif mode == 4:
            # rotate 180 degree
            return np.rot90(image, k=2)
```

```
        elif mode == 5:
            # rotate 180 degree and flip
            image = np.rot90(image, k=2)
            return np.flipud(image)
        elif mode == 6:
            # rotate 270 degree
            return np.rot90(image, k=3)
        elif mode == 7:
            # rotate 270 degree and flip
            image = np.rot90(image, k=3)
            return np.flipud(image)

    class lowlight_enhance:

      def __init__(self, train_low_data, train_high_data, eval_low_data, batch_size, patch_size,

        self.DecomNet_layer_num = 5
        self.sess = tf.Session()

        self.train_low_data = train_low_data
        self.train_high_data = train_high_data
        self.eval_low_data = eval_low_data
        self.batch_size = batch_size
        self.patch_size = patch_size
        self.epoch = epoch
        self.learning_rate = learning_rate
        self.train_phase = train_phase

        self.train_low_data_ph = tf.placeholder(tf.float32, [None, None, None, 3], name='train_lo
        self.train_high_data_ph = tf.placeholder(tf.float32, [None, None, None, 3], name='train_h
        self.lr_ph = tf.placeholder(tf.float32, name='lr_ph')

        self.ckpt_dir = ckpt_dir

        [R_low, I_low] = DecomNet(self.train_low_data_ph, layer_num=self.DecomNet_layer_num)
        [R_high, I_high] = DecomNet(self.train_high_data_ph, layer_num=self.DecomNet_layer_num)

        I_low_3 = concat([I_low, I_low, I_low])
        I_high_3 = concat([I_high, I_high, I_high])

        self.output_R_low = R_low
        self.output_I_low = I_low_3

        # loss
        self.recon_loss_low = tf.reduce_mean(tf.abs(R_low * I_low_3 -  self.train_low_data_ph))
        self.recon_loss_high = tf.reduce_mean(tf.abs(R_high * I_high_3 - self.train_high_data_ph)
        self.recon_loss_mutal_low = tf.reduce_mean(tf.abs(R_high * I_low_3 - self.train_low_data_
        self.recon_loss_mutal_high = tf.reduce_mean(tf.abs(R_low * I_high_3 - self.train_high_dat
        self.equal_R_loss = tf.reduce_mean(tf.abs(R_low - R_high))

        self.Ismooth_loss_low = self.smooth(I_low, R_low)
```

```
    self.Ismooth_loss_high = self.smooth(I_high, R_high)

    self.loss_Decom = self.recon_loss_low + self.recon_loss_high + 0.001 * self.recon_loss_mu

    self.lr_ph = tf.placeholder(tf.float32, name='learning_rate')
    optimizer = tf.train.AdamOptimizer(self.lr_ph, name='AdamOptimizer')

    self.var_Decom = [var for var in tf.trainable_variables() if 'DecomNet' in var.name]

    self.train_op_Decom = optimizer.minimize(self.loss_Decom, var_list = self.var_Decom)

    self.sess.run(tf.global_variables_initializer())

    self.saver_Decom = tf.train.Saver(var_list = self.var_Decom)

    print("[*] Initialize model successfully...")

  def gradient(self, input_tensor, direction):
    self.smooth_kernel_x = tf.reshape(tf.constant([[0, 0], [-1, 1]], tf.float32), [2, 2, 1, 1
    self.smooth_kernel_y = tf.transpose(self.smooth_kernel_x, [1, 0, 2, 3])

    if direction == "x":
        kernel = self.smooth_kernel_x
    elif direction == "y":
        kernel = self.smooth_kernel_y
    return tf.abs(tf.nn.conv2d(input_tensor, kernel, strides=[1, 1, 1, 1], padding='SAME'))

  def ave_gradient(self, input_tensor, direction):
    return tf.layers.average_pooling2d(self.gradient(input_tensor, direction), pool_size=3, s

  def smooth(self, input_I, input_R):
    input_R = tf.image.rgb_to_grayscale(input_R)
    return tf.reduce_mean(self.gradient(input_I, "x") * tf.exp(-10 * self.ave_gradient(input_

  def evaluate_test(self):

    print("Evaluating for test data")
    Reflectance = []
    Illuminance = []

    for idx in range(len(self.eval_low_data)):
      input_low_eval = np.expand_dims(self.eval_low_data[idx], axis=0)

      if train_phase == "Decom":
        result_1, result_2 = self.sess.run([self.output_R_low, self.output_I_low], feed_dict=

      Reflectance.append(result_1)
      Illuminance.append(result_2)

    return Reflectance, Illuminance
```

```
  def evaluate_train(self):

    print("Evaluating for train data")
    Reflectance = []
    Illuminance = []

    for idx in tqdm(range(len(self.train_low_data))):
    #for idx in tqdm(range(start_id, end_id)):
      input_low_train = np.expand_dims(self.train_low_data[idx], axis=0)

      if train_phase == "Decom":
        result_1, result_2 = self.sess.run([self.output_R_low, self.output_I_low], feed_dict=

      Reflectance.append(result_1)
      Illuminance.append(result_2)

    return Reflectance, Illuminance

  def train(self):

    numBatch = 30

    # load pretrained model

    train_op = self.train_op_Decom
    train_loss = self.loss_Decom
    saver = self.saver_Decom

    iter_num = 0
    start_epoch = 0
    start_step = 0
    lr1 = self.learning_rate

    start_time = time.time()
    image_id = 0

    for epoch in range(start_epoch, self.epoch):

      for batch_id in range(start_step, numBatch):

        # generate data for a batch
        batch_input_low = np.zeros((self.batch_size, self.patch_size, self.patch_size, 3), dt
        batch_input_high = np.zeros((self.batch_size, self.patch_size, self.patch_size, 3), d
        for patch_id in range(self.batch_size):

          h, w, _ = self.train_low_data[image_id].shape
          x = random.randint(0, h - self.patch_size)
          y = random.randint(0, w - self.patch_size)

          rand_mode = random.randint(0, 7)
          batch_input_low[patch_id, :, :, :] = data_augmentation(self.train_low_data[image_id
```

```
            batch_input_high[patch_id, :, :, :] = data_augmentation(self.train_high_data[image_

            image_id = (image_id + 1) % len(self.train_low_data)
            if image_id == 0:
              tmp = list(zip(self.train_low_data, self.train_high_data))
              random.shuffle(list(tmp))
              train_low_data, train_high_data  = zip(*tmp)

          # train
          _, loss = self.sess.run([train_op, train_loss], feed_dict={self.train_low_data_ph: ba
                                                                     self.train_high_data_ph:
                                                                     self.lr_ph: lr1[epoch]})

          print("%s Epoch: [%2d] [%4d/%4d] time: %4.4f, loss: %.6f" \
                % (train_phase, epoch + 1, batch_id + 1, numBatch, time.time() - start_time, lo
          iter_num += 1

    def save_pretrained(self):
      self.save(self.saver_Decom, self.ckpt_dir, "RetinexNet-%s" % self.train_phase)

    def load_pretrained(self):
      load_model_status = self.load(self.saver_Decom, self.ckpt_dir)
      print("[*] Model restore success!")

    def save(self, saver, ckpt_dir, model_name):
      if not os.path.exists(ckpt_dir):
        os.makedirs(ckpt_dir)
      print("[*] Saving model %s" % model_name)
      saver.save(self.sess, \
                 os.path.join(ckpt_dir, model_name), \
                )

    def load(self, saver, ckpt_dir):
      ckpt = tf.train.get_checkpoint_state(ckpt_dir)
      full_path = ckpt_dir + '/RetinexNet-Decom'

      saver.restore(self.sess, full_path)
      return True



epoch = 100
#epoch = 10
learning_rate = 0.001 * np.ones([epoch])
learning_rate[20:] = learning_rate[0] / 10.0
batch_size = 16
patch_size = 48
train_phase = "Decom"
ckpt_dir = "/content/drive/MyDrive/Case_study_2"
```

```
model = lowlight_enhance(train_low_data, train_high_data, eval_low_data, batch_size, patch_si

model.save_pretrained()
```

```
    [*] Saving model RetinexNet-Decom
```

```
model.load_pretrained()
```

```
    INFO:tensorflow:Restoring parameters from /content/drive/MyDrive/Case_study_2/RetinexNet
    [*] Model restore success!
```

```
Reflectance, Illuminance = model.evaluate_train()
```

```
    Evaluating for train data
    100%|██████████| 5000/5000 [00:14<00:00, 350.94it/s]
```

```
Reflectance_test, Illuminance_test = model.evaluate_test()
```

```
    Evaluating for test data
```

Plotting Reflectance and Illuminantion of a sample image

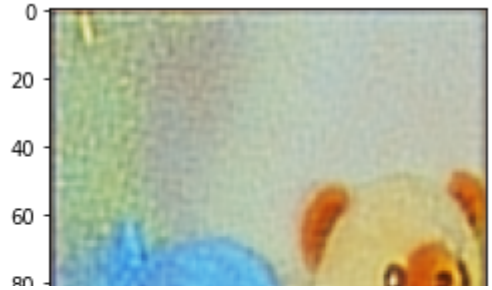
```
R_img = Reflectance[0]
I_img = Illuminance[0]

R_img = R_img[0,:,:,:]
I_img = I_img[0,:,:,:]

#print(img.shape)
print(R_img.shape)
print(I_img.shape)
```

```
    (128, 128, 3)
    (128, 128, 3)
```

Plotting Reflectance of an image

```
plt.imshow(R_img[ : , : , :])
```

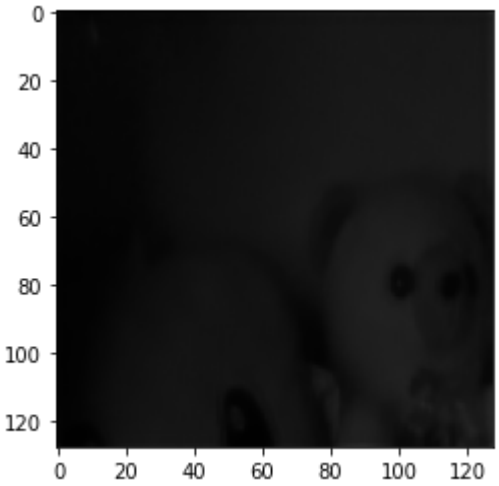
```
<matplotlib.image.AxesImage at 0x7fb4d9efae10>
```



Plotting Illuminance of an image

```
plt.imshow(I_img[ : , : , :])
```

```
<matplotlib.image.AxesImage at 0x7fb4d9e70610>
```



Adjustment

```
Reflectance_1 = list()
for i in tqdm(range(len(Reflectance))):
  R = Reflectance[i]
  R1 = R[0,:,:,:]
  Reflectance_1.append(R1)
```

```
100%|██████████| 5000/5000 [00:00<00:00, 528622.71it/s]
```

```
Illuminance_1 = list()
for i in tqdm(range(len(Illuminance))):
  I = Illuminance[i]
  I1 = I[0,:,:,:]
  Illuminance_1.append(I1)
```

```
100%|██████████| 5000/5000 [00:00<00:00, 678843.75it/s]
```

```
Reflectance_111 = np.array(Reflectance_1, dtype='float32')
Reflectance_111.shape
```

```
(5000, 128, 128, 3)
```

```
Illuminance_111 = np.array(Illuminance_1, dtype='float32')
Illuminance_111.shape
```

```
(5000, 128, 128, 3)
```

```
Reflectance_test_1 = list()
for i in tqdm(range(len(Reflectance_test))):
  R = Reflectance_test[i]
  R1 = R[0,:,:,:]
  Reflectance_test_1.append(R1)
```

```
100%|██████████| 15/15 [00:00<00:00, 46465.70it/s]
```

```
Illuminance_test_1 = list()
for i in tqdm(range(len(Illuminance_test))):
  I = Illuminance_test[i]
  I1 = I[0,:,:,:]
  Illuminance_test_1.append(I1)
```

```
100%|██████████| 15/15 [00:00<00:00, 47197.72it/s]
```

```
Reflectance_test_111 = np.array(Reflectance_test_1, dtype='float32')
Reflectance_test_111.shape
```

```
(15, 128, 128, 3)
```

```
Illuminance_test_111 = np.array(Illuminance_test_1, dtype='float32')
Illuminance_test_111.shape
```

```
(15, 128, 128, 3)
```

```
class lowlight_enhance_2:

  def __init__(self, train_high_data,  Reflectance, Illuminance, Reflectance_test, Illuminanc

    self.sess = tf.Session()

    self.train_high_data = train_high_data

    self.R_low = Reflectance
```

```
        self.I_low = Illuminance

        self.R_low_test = Reflectance_test
        self.I_low_test = Illuminance_test

        self.batch_size = batch_size
        self.patch_size = patch_size
        self.epoch = epoch
        self.learning_rate = learning_rate
        self.train_phase = train_phase

        self.train_high_data_ph = tf.placeholder(tf.float32, [None, None, None, 3], name='train_h
        self.R_low_ph = tf.placeholder(tf.float32, [None, None, None, 3], name='R_low_ph')
        self.I_low_ph = tf.placeholder(tf.float32, [None, None, None, 3], name='I_low_ph')

        self.lr_ph = tf.placeholder(tf.float32, name='lr_ph')

        self.ckpt_dir_2 = ckpt_dir_2

        I_delta = RelightNet(self.I_low_ph, self.R_low_ph)

        I_delta_3 = concat([I_delta, I_delta, I_delta])

        self.output_I_delta = I_delta_3

        self.output_S = self.R_low_ph * I_delta_3

        self.relight_loss = tf.reduce_mean(tf.abs(self.R_low_ph * I_delta_3 - self.train_high_dat

        self.Ismooth_loss_delta = self.smooth(I_delta, self.R_low_ph)

        self.loss_Relight = self.relight_loss + 3 * self.Ismooth_loss_delta

        self.lr_ph = tf.placeholder(tf.float32, name='learning_rate')
        optimizer = tf.train.AdamOptimizer(self.lr_ph, name='AdamOptimizer')

        self.var_Relight = [var for var in tf.trainable_variables() if 'RelightNet' in var.name]

        self.train_op_Relight = optimizer.minimize(self.loss_Relight, var_list = self.var_Relight

        self.sess.run(tf.global_variables_initializer())

        self.saver_Relight = tf.train.Saver(var_list = self.var_Relight)

        print("[*] Initialize model successfully...")

    def gradient(self, input_tensor, direction):
        self.smooth_kernel_x = tf.reshape(tf.constant([[0, 0], [-1, 1]], tf.float32), [2, 2, 1, 1
        self.smooth_kernel_y = tf.transpose(self.smooth_kernel_x, [1, 0, 2, 3])

        if direction == "x":
```

```
            kernel = self.smooth_kernel_x
        elif direction == "y":
            kernel = self.smooth_kernel_y
        return tf.abs(tf.nn.conv2d(input_tensor, kernel, strides=[1, 1, 1, 1], padding='SAME'))

    def ave_gradient(self, input_tensor, direction):
        return tf.layers.average_pooling2d(self.gradient(input_tensor, direction), pool_size=3, s

    def smooth(self, input_I, input_R):
        input_R = tf.image.rgb_to_grayscale(input_R)
        return tf.reduce_mean(self.gradient(input_I, "x") * tf.exp(-10 * self.ave_gradient(input_

    def evaluate_test(self):

        print("Evaluating for test data")
        R_low_hat = []
        I_low_hat = []

        for idx in range(len(self.R_low_test)):
            input_R_low = np.expand_dims(self.R_low_test[idx], axis=0)
            input_I_low = np.expand_dims(self.I_low_test[idx], axis=0)

            if train_phase == "Relight":
                result_1, result_2 = self.sess.run([self.output_S, self.output_I_delta], feed_dict={s

            R_low_hat.append(result_1)
            I_low_hat.append(result_2)

        return R_low_hat, I_low_hat

    def evaluate_train(self):

        print("Evaluating for train data")
        R_low_hat = []
        I_low_hat = []

        for idx in tqdm(range(len(self.R_low))):
        #for idx in tqdm(range(start_id, end_id)):
            input_R_low = np.expand_dims(self.R_low[idx], axis=0)
            input_I_low = np.expand_dims(self.I_low[idx], axis=0)

            if train_phase == "Relight":
                result_1, result_2 = self.sess.run([self.output_S, self.output_I_delta], feed_dict={s

            R_low_hat.append(result_1)
            I_low_hat.append(result_2)

        return R_low_hat, I_low_hat

    def train(self):
```

```
    numBatch = 30

    train_op = self.train_op_Relight
    train_loss = self.loss_Relight
    saver = self.saver_Relight

    iter_num = 0
    start_epoch = 0
    start_step = 0
    lr1 = self.learning_rate

    start_time = time.time()
    image_id = 0

    for epoch in range(start_epoch, self.epoch):

      for batch_id in range(start_step, numBatch):

        # generate data for a batch
        batch_R_low = np.zeros((self.batch_size, 128, 128, 3), dtype="float32")
        batch_I_low = np.zeros((self.batch_size, 128, 128, 3), dtype="float32")
        batch_input_high = np.zeros((self.batch_size, 128, 128, 3), dtype="float32")

        for patch_id in range(self.batch_size):

          batch_R_low[patch_id, :, :, :] = self.R_low[image_id, :, :, :]
          batch_I_low[patch_id, :, :, :] = self.I_low[image_id, :, :, :]
          batch_input_high[patch_id, :, :, :] = self.train_high_data[image_id][:,:,:]

          image_id = (image_id + 1) % len(self.R_low)
          if image_id == 0:
            tmp = list(zip(self.R_low, self.I_low))
            random.shuffle(list(tmp))
            R_low, I_low  = zip(*tmp)

        # train
        _, loss = self.sess.run([train_op, train_loss], feed_dict={self.R_low_ph: batch_R_low
                                                                   self.I_low_ph: batch_I_lo
                                                                   self.lr_ph: lr1[epoch], \
                                                                   self.train_high_data_ph:

        print("%s Epoch: [%2d] [%4d/%4d] time: %4.4f, loss: %.6f" \
              % (train_phase, epoch + 1, batch_id + 1, numBatch, time.time() - start_time, lo
        iter_num += 1

  def save_pretrained_2(self):
    self.save_2(self.saver_Relight, self.ckpt_dir_2, "RetinexNet-%s" % self.train_phase)

  def load_pretrained_2(self):
    load_model_status = self.load_2(self.saver_Relight, self.ckpt_dir_2)
    print("[*] Model restore success!")
```

```
  def save_2(self, saver, ckpt_dir, model_name):
    if not os.path.exists(ckpt_dir):
      os.makedirs(ckpt_dir)
    print("[*] Saving model %s" % model_name)
    saver.save(self.sess, \
               os.path.join(ckpt_dir, model_name))

  def load_2(self, saver, ckpt_dir):
    ckpt = tf.train.get_checkpoint_state(ckpt_dir)
    full_path = ckpt_dir + '/RetinexNet-Relight'

    saver.restore(self.sess, full_path)
    return True


train_phase = "Relight"
ckpt_dir_2 = "/content/drive/MyDrive/Case_study_2"


model2 = lowlight_enhance_2(train_high_data, Reflectance_111, Illuminance_111, Reflectance_te
```

```
[*] Initialize model successfully...
```

```
model2.save_pretrained_2()
```

```
[*] Saving model RetinexNet-Relight
```

```
model2.load_pretrained_2()
```

```
INFO:tensorflow:Restoring parameters from /content/drive/MyDrive/Case_study_2/RetinexNet
[*] Model restore success!
```

```
Output_S, Output_I_delta = model2.evaluate_train()
```

```
Evaluating for train data
100%|██████████| 5000/5000 [00:12<00:00, 398.14it/s]
```

```
Output_S_test, Output_I_delta_test = model2.evaluate_test()
```

```
Evaluating for test data
```

Plotting a sample low light and high light image (training data)

```
hl_img = Output_S[0]
hl_img2 = Output_I_delta[0]
```

```
hl_img = hl_img[0,:,:,:]
hl_img2 = hl_img2[0,:,:,:]

#print(img.shape)
print(hl_img.shape)
print(hl_img2.shape)
```

```
(128, 128, 3)
(128, 128, 3)
```

Sample low light image

```
low_img = train_low_data[0]
print("Shape of the image", low_img.shape)
```

```
Shape of the image (128, 128, 3)
```

Sample high light image

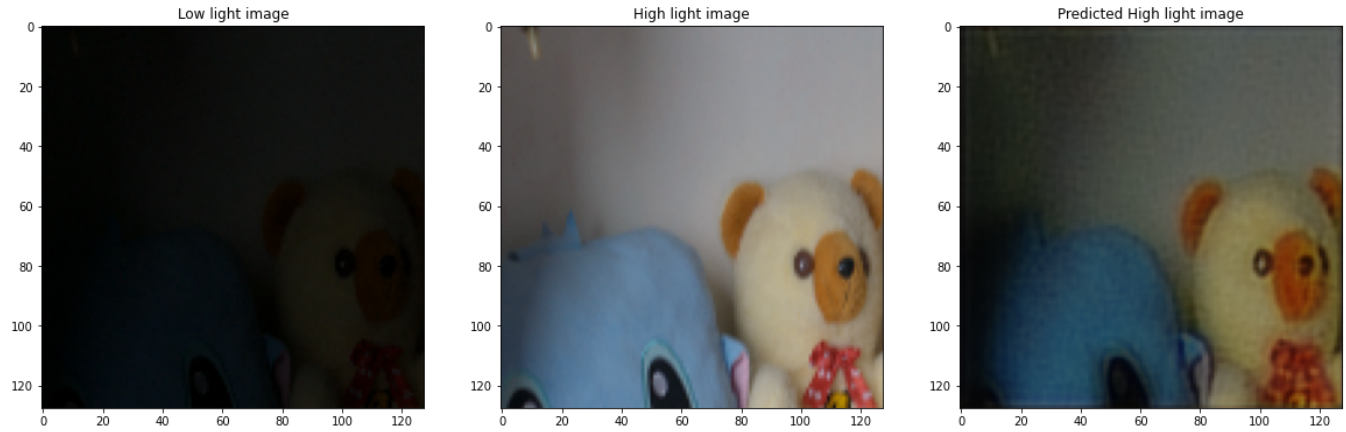
```
high_img = train_high_data[0]
print("Shape of the image", high_img.shape)
```

```
Shape of the image (128, 128, 3)
```

Sample predicted high light image

```
hl_image_final = hl_img*hl_img2


plt.figure(figsize=(20,12))

plt.subplot(1,3,1)
plt.imshow(low_img[ : , : , :])
plt.title('Low light image')

plt.subplot(1,3,2)
plt.imshow(high_img[ : , : , :])
plt.title('High light image')

plt.subplot(1,3,3)
plt.imshow(hl_image_final[ : , : , :])
plt.title('Predicted High light image')
```

```
Text(0.5, 1.0, 'Predicted High light image')
```



Plotting a sample low light and high light image (testing data)

```
hl_img = Output_S_test[0]
hl_img2 = Output_I_delta_test[0]

hl_img = hl_img[0,:,:,:]
hl_img2 = hl_img2[0,:,:,:]

print(hl_img.shape)
print(hl_img2.shape)
```

```
(128, 128, 3)
(128, 128, 3)
```

Sample low light image

```
low_img = eval_low_data[0]
print("Shape of the image", low_img.shape)
```

```
Shape of the image (128, 128, 3)
```

Sample high light image

```
high_img = eval_high_data[0]
print("Shape of the image", high_img.shape)
```

```
Shape of the image (128, 128, 3)
```

Sample predicted high light image

```
hl_image_final = hl_img*hl_img2


plt.figure(figsize=(20,12))

plt.subplot(1,3,1)
plt.imshow(low_img[ : , : , :])
plt.title('Low light image')

plt.subplot(1,3,2)
plt.imshow(high_img[ : , : , :])
plt.title('High light image')

plt.subplot(1,3,3)
plt.imshow(hl_image_final[ : , : , :])
plt.title('Predicted High light image')
```

```
Text(0.5, 1.0, 'Predicted High light image')
```