Image Restoration

June 26, 2020

1 Import Libraries

[1]:
```
import tensorflow as tf
from tensorflow.keras.layers import Input, Reshape
from tensorflow.keras.optimizers import Adam
from tensorflow.keras import backend as K
from tensorflow.keras.callbacks import Callback
from tensorflow.keras.models import Model
from skimage.transform import radon, rescale
import matplotlib.pyplot as plt
import numpy as np
import cv2
from model import get_Model
import time
from rrmse import rrmse
import random as python_random

tf.random.set_seed(100)
np.random.seed(1)
python_random.seed(123)

print(tf.__version__)

import os

os.environ['TF_FORCE_GPU_ALLOW_GROWTH'] = 'true'
```

```
0.2721655269759087
2.3.0-dev20200618
```

[2]:
```
class BMCallback(Callback):
        def __init__(self):
                self.best_weights = None
                self.min_loss = 1

        def on_epoch_end(self, epoch, logs=None):
                if logs['loss'] < self.min_loss:
```

```
                        self.min_loss = logs['loss']
                        self.best_weights = self.model.get_weights()

def mse_masked(mask):
        def loss_func(y_true, y_pred):
                return K.mean(K.square((y_pred - y_true) * mask))
        return loss_func

def rrmse_gr(gr):
        def loss_func(y_true, y_pred):
                return K.sqrt(K.sum(K.square(y_pred - gr))/K.sum(K.square(gr)))
        return loss_func

def scaled_loss(scale_exp):
        def loss_func(y_true, y_pred):
                s = 2**scale_exp
                down_ypred = y_pred[:,::s,::s] * 0
                for i in range(s):
                        for j in range(s):
                                down_ypred = down_ypred + y_pred[:, i::s, j::s]
                down_ypred = down_ypred / s**2

                mse = K.mean(K.square(y_true - down_ypred))
                var = K.mean(K.square(y_pred[:,1:,:] - y_pred[:,:-1,:])) + K.
 ↪mean(K.square(y_pred[:,:,1:] - y_pred[:,:,:-1]))
                return mse + var/12
        return loss_func
```

2 Cat Text Removal

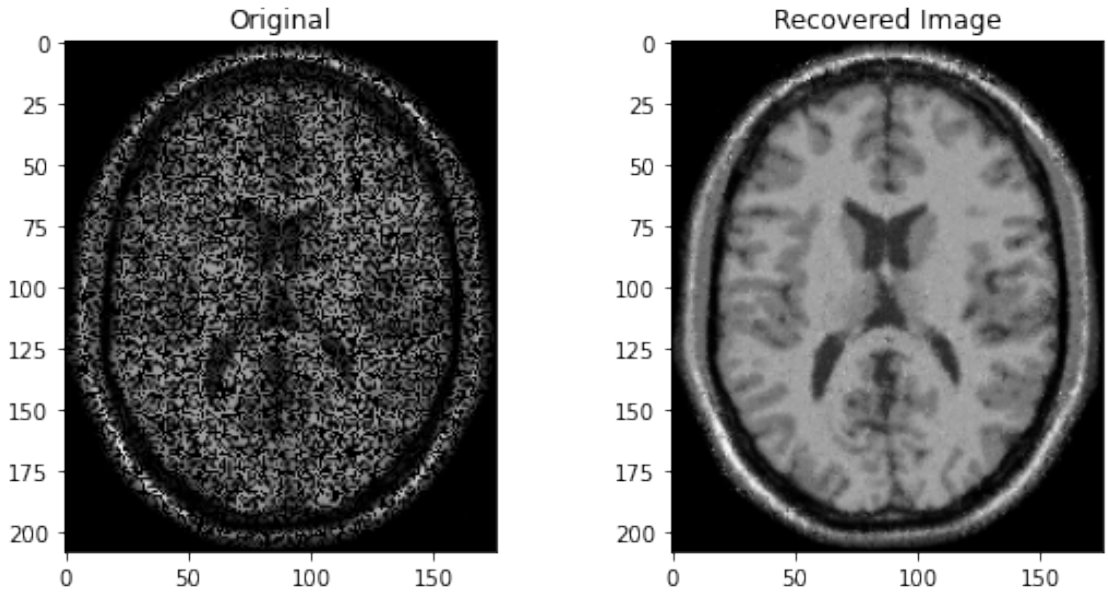
[3]:
```
cat_img = plt.imread('data/cat.png')[:,:,:3]
M, N, C = cat_img.shape

mask = (np.sum(cat_img, axis=2) > 0).reshape(M, N, 1)        # pixels of text␣
 ↪are (0,0,0) (black)

F = 16

model = get_Model(Input((M, N, F)), n_filters=16, depth=4, output_channels=C)
model.compile(optimizer=Adam(), loss=mse_masked(mask))


z = np.random.uniform(low=-1, high=1, size=(1,M,N,F))

bmcb = BMCallback()
```

```
hist = model.fit(z, cat_img.reshape((1,M,N,C)), epochs=2000, verbose=0,␣
 ↪callbacks=[bmcb])
model.set_weights(bmcb.best_weights)


rec_cat_img = model.predict(z)[0]

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 6))

ax1.set_title("Original")
ax1.imshow(cat_img)
ax2.set_title("Recovered Image")
ax2.imshow(rec_cat_img)
fig.tight_layout()
plt.show()
```

3 MRI Inpainting

[5]:
```
mri_img = plt.imread('data/brain_mri.png')
M, N = mri_img.shape
mri_img = mri_img.reshape((M,N,1))
mask = np.random.uniform(size=(M,N,1)) > 0.5

img = mri_img * mask

F = 16

model = get_Model(Input((M, N, F)), n_filters=16, depth=4, output_channels=1)
model.compile(optimizer=Adam(), loss=mse_masked(mask))

np.random.seed(2)
z = np.random.uniform(low=-1, high=1, size=(1,M,N,F))

bmcb = BMCallback()
```

```
hist = model.fit(z, img.reshape((1,M,N,1)), epochs=1800, verbose=0,␣
 ↪callbacks=[bmcb])
model.set_weights(bmcb.best_weights)

rec_img = model.predict(z)[0,:,:,0]

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(8, 4))

ax1.set_title("Original")
ax1.imshow(img[:, :, 0], cmap='gray')
ax2.set_title("Recovered Image")
ax2.imshow(rec_img, cmap='gray')
fig.tight_layout()

plt.show()
```



4 MRI Denoising

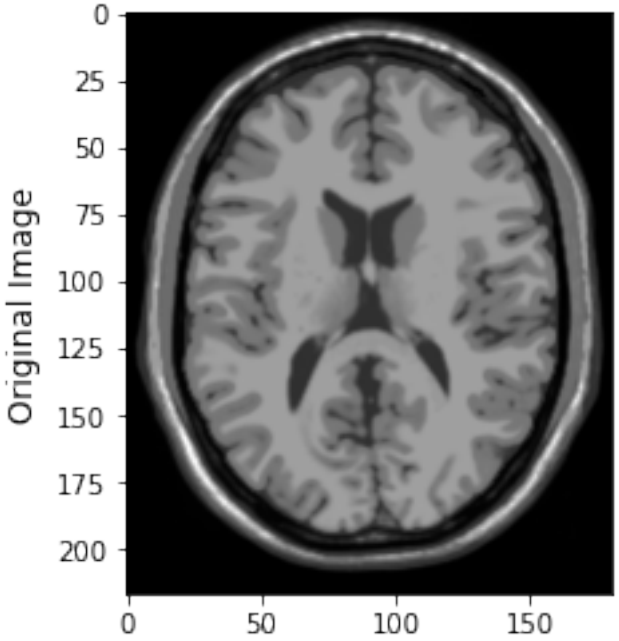
[3]:
```
def denoise(noiseless_img_path, noisy_img_path, lr, epochs, depth=4):
        nl_img = plt.imread(noiseless_img_path)
        noisy_img = plt.imread(noisy_img_path)

        if len(nl_img.shape) == 3:
                M, N, C = nl_img.shape
        else:
```

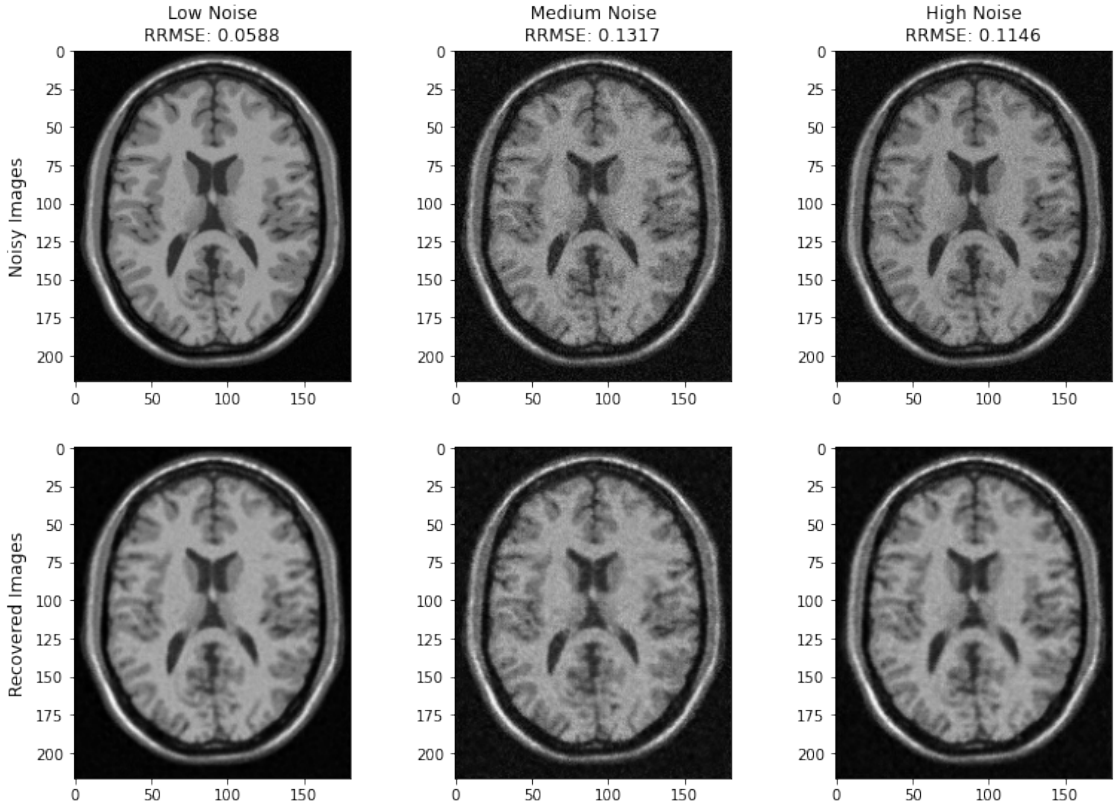
```
                M, N = nl_img.shape
                C = 1

        Mp = (M//(2**depth) + 1)*(2**depth)
        Np = (N//(2**depth) + 1)*(2**depth)
        x = (Np-N)
        y = (Mp-M)
        noisy_imgp = cv2.copyMakeBorder(noisy_img.copy(),0,y,0,x,cv2.
↪BORDER_CONSTANT,value=[0,0,0])
        nl_imgp = cv2.copyMakeBorder(nl_img.copy(),0,y,0,x,cv2.
↪BORDER_CONSTANT,value=[0,0,0])

        noisy_imgp = noisy_imgp.reshape((Mp, Np, C))
        nl_imgp = nl_imgp.reshape((Mp, Np, C))

        F = 16

        z = np.random.uniform(low=-1, high=1, size=(1,Mp,Np,F))


        model = get_Model(Input((Mp, Np, F)), n_filters=8, depth=depth,␣
↪output_channels=C)
        model.compile(optimizer=Adam(lr=lr), loss='mse',␣
↪metrics=[rrmse_gr(nl_imgp)])
        hist = model.fit(z, noisy_imgp.reshape((1,Mp,Np,C)), epochs=epochs,␣
↪verbose=0)
        rec_img = model.predict(z)[0]

        if C == 1:
                rec_img = rec_img[:M, :N, 0]
        else:
                rec_img = rec_img[:M, :N, :]

        return nl_img, noisy_img, rec_img
```

[4]:
```
nl_img_path = 'data/mri_image_noiseless.png'
low_noise_img_path = 'data/mri_image_noise_level_low.png'
med_noise_img_path = 'data/mri_image_noise_level_medium.png'
high_noise_img_path = 'data/mri_image_noise_level_high.png'
noisy_img_paths = [low_noise_img_path, high_noise_img_path, med_noise_img_path]
titles = ['Low Noise', 'Medium Noise', 'High Noise']
lrs = [0.001, 0.001, 0.001]
epochs = [1400, 1200, 1100]

start = 0                       # modify these to recover particular set of␣
↪images
```

```
end = len(noisy_img_paths)

noisy_imgs = []
rec_imgs = []
title_imgs = []
for i in range(start, end):
        nl_mri_img, noisy_mri_img, rec_mri_img = denoise(nl_img_path,␣
 ↪noisy_img_paths[i], lrs[i], epochs[i])
        noisy_imgs.append(noisy_mri_img)
        rec_imgs.append(rec_mri_img)
        title_imgs.append(titles[i])

plt.imshow(nl_mri_img, cmap='gray')
plt.ylabel('Original Image', size='large', labelpad=5)

fig, axes = plt.subplots(2, end-start, figsize=(13, 9))
axes = axes.reshape((2, end-start))
for i in range(0, end-start):
        axes[0, i].imshow(noisy_imgs[i], cmap='gray')
        axes[1, i].imshow(rec_imgs[i], cmap='gray')
        axes[0, i].set_title(title_imgs[i]+f'\nRRMSE: {rrmse(nl_mri_img,␣
 ↪rec_imgs[i]):.4f}')

axes[0, 0].set_ylabel('Noisy Images',  size='large', labelpad=5)
axes[1, 0].set_ylabel('Recovered Images', size='large', labelpad=5)
```

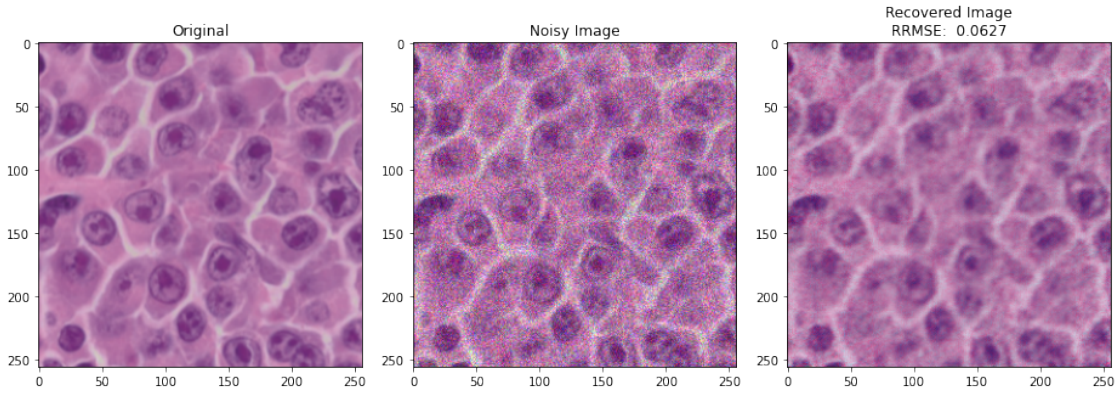
[4]: Text(0, 0.5, 'Recovered Images')





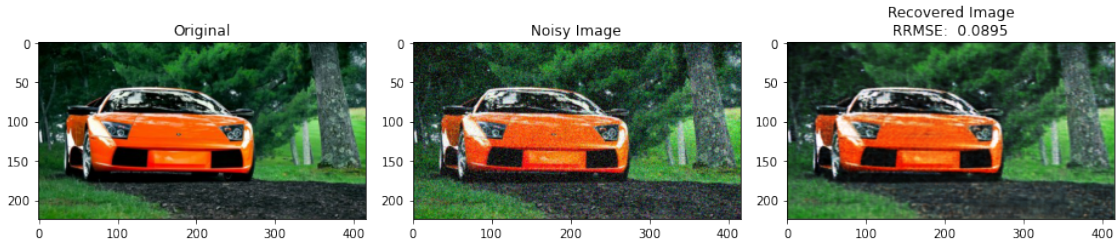
5 Denoising Histology

[4]:
```
nl_histology_img_path = 'data/histology_noiseless.png'
noisy_histology_img_path = 'data/histology_noisy.png'

nl_hist_img, noisy_hist_img, rec_hist_img = denoise(nl_histology_img_path,␣
↪noisy_histology_img_path, lr=0.0003, epochs=1600)

fig, (ax1, ax2, ax3) = plt.subplots(1, 3, figsize=(13, 8))

ax1.set_title("Original")
ax1.imshow(nl_hist_img)
ax2.set_title("Noisy Image")
ax2.imshow(noisy_hist_img)
ax3.set_title(f"Recovered Image\nRRMSE: {rrmse(nl_hist_img, rec_hist_img): 0.
↪4f}")
ax3.imshow(rec_hist_img)
fig.tight_layout()
```



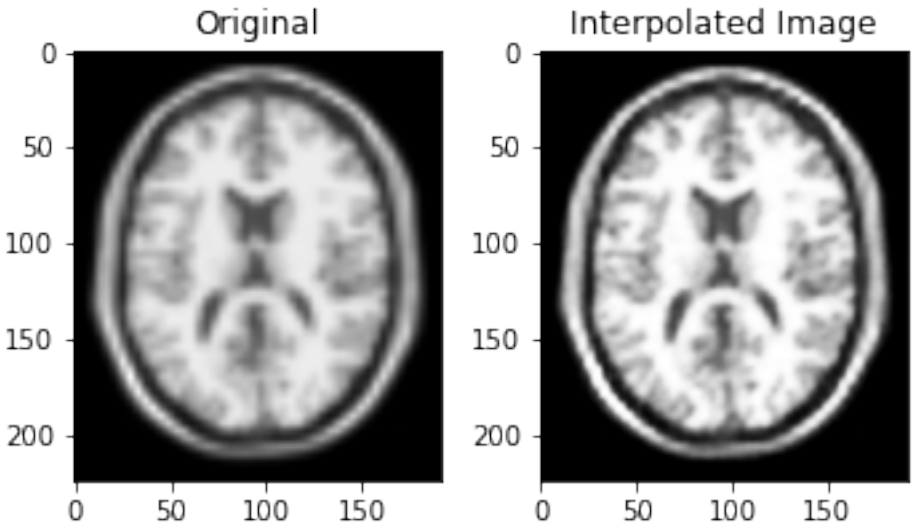
6 Denoising Car

[5]:
```
nl_car_img = plt.imread('data/car.png')
M, N, C = nl_car_img.shape
sigma = 0.1
noisy_car_img = nl_car_img + sigma * np.random.randn(M, N, C)
noisy_car_img = np.vectorize(lambda x: 1.0 if x>1 else 0.0 if x<0 else␣
 ↪x)(noisy_car_img)

F = 16

model = get_Model(Input((M, N, F)), n_filters=8, depth=4, output_channels=C)
model.compile(optimizer=Adam(), loss='mse', metrics=[rrmse_gr(nl_car_img)])

np.random.seed(2)
z = np.random.uniform(low=-1, high=1, size=(1,M,N,F))

model.fit(z, noisy_car_img.reshape((1,M,N,C)), epochs=1600, verbose=0)

rec_car_img = model.predict(z)[0]

fig, (ax1, ax2, ax3) = plt.subplots(1, 3, figsize=(13, 8))

ax1.set_title("Original")
ax1.imshow(nl_car_img)
ax2.set_title("Noisy Image")
ax2.imshow(noisy_car_img)
ax3.set_title(f"Recovered Image\nRRMSE: {rrmse(nl_car_img, rec_car_img): 0.4f}")
ax3.imshow(rec_car_img)
fig.tight_layout()
```



7 Super Resolution

[6]:
```
mri_img = np.zeros((56,48))
mri_img[2:-2,2:-2] = plt.imread('data/mri_lowres.png')
M, N = mri_img.shape
F = 16

model = get_Model(Input((M, N, F)), n_filters=16, depth=3, res_exp=2,␣
 ↪output_channels=1)
model.compile(optimizer=Adam(), loss=scaled_loss(2))

z = np.random.uniform(low=-1, high=1, size=(1,M,N,F))

bmcb = BMCallback()

hist = model.fit(z, mri_img.reshape((1,M,N,1)), epochs=3000, verbose=0,␣
 ↪callbacks=[bmcb])
model.set_weights(bmcb.best_weights)

rec_highres_mri_img = model.predict(z)[0]

fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(5, 3))

ax1.set_title("Original")
from skimage.transform import resize
ax1.imshow(resize(mri_img, (4*M, 4*N)), cmap='gray')
ax2.set_title("Interpolated Image")
ax2.imshow(rec_highres_mri_img[:,:,0], cmap='gray')
fig.tight_layout()

plt.show()
```


Original
Interpolated Image
0
50
100
150
200
0
50
100
150