IHS

December 6, 2023

1 Dataset

- Satellite- WorldView-3
- Ground sampling distance- 0.31m PAN 1.24m MS
- The number of bands for MS image- 8
- The radiometric resolution in bits- 11
- Location- Munich, Germany

2 Import Packages

[1]:
```
import numpy as np
import cv2
import os
import scipy.io as sio
from scipy import ndimage
from scipy import signal
import scipy.misc as misc
from PIL import Image
from IPython.display import display, HTML
```

3 Utils

[2]:
```
def upsample_interp23(image, ratio):

    image = np.transpose(image, (2, 0, 1))

    b,r,c = image.shape

    CDF23 = 2*np.array([0.5, 0.305334091185, 0, -0.072698593239, 0, 0.
↪021809577942, 0, -0.005192756653, 0, 0.000807762146, 0, -0.000060081482])
    d = CDF23[::-1]
    CDF23 = np.insert(CDF23, 0, d[:-1])
    BaseCoeff = CDF23

    first = 1
    for z in range(1,int(np.log2(ratio))+1):
```

```
        I1LRU = np.zeros((b, 2**z*r, 2**z*c))
        if first:
            I1LRU[:, 1:I1LRU.shape[1]:2, 1:I1LRU.shape[2]:2]=image
            first = 0
        else:
            I1LRU[:,0:I1LRU.shape[1]:2,0:I1LRU.shape[2]:2]=image

        for ii in range(0,b):
            t = I1LRU[ii,:,:]
            for j in range(0,t.shape[0]):
                t[j,:]=ndimage.correlate(t[j,:],BaseCoeff,mode='wrap')
            for k in range(0,t.shape[1]):
                t[:,k]=ndimage.correlate(t[:,k],BaseCoeff,mode='wrap')
            I1LRU[ii,:,:]=t
        image = I1LRU

    re_image=np.transpose(I1LRU, (1, 2, 0))

    return re_image
```

4 IHS

[3]:
```
import numpy as np
#from utils import upsample_interp23

def IHS(pan, hs):
    M, N, c = pan.shape
    m, n, C = hs.shape

    ratio = int(np.round(M/m))

    print('get sharpening ratio: ', ratio)
    assert int(np.round(M/m)) == int(np.round(N/n))

    #upsample
    u_hs = upsample_interp23(hs, ratio)

    I = np.mean(u_hs, axis=-1, keepdims=True)

    P = (pan - np.mean(pan))*np.std(I, ddof=1)/np.std(pan, ddof=1)+np.mean(I)

    I_IHS = u_hs + np.tile(P-I, (1, 1, C))

    #adjustment
    I_IHS[I_IHS<0]=0
    I_IHS[I_IHS>1]=1
```

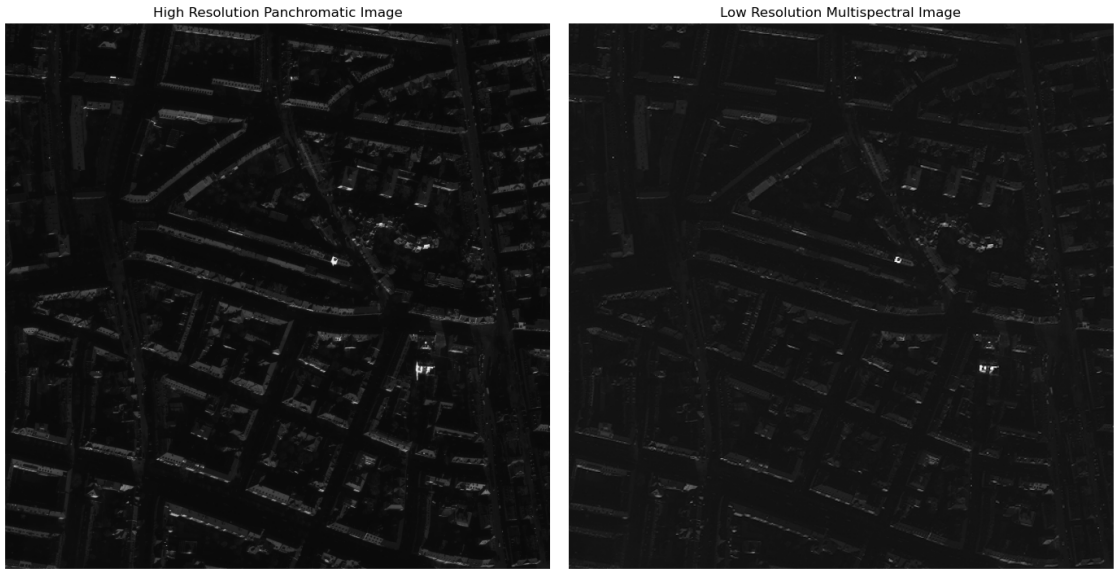
```
    return np.uint8(I_IHS*255)
```

5 Load and Display Panchromatic and Multispectral Image

[4]:
```
import imageio.v2 as imageio
import matplotlib.pyplot as plt

# Specify the path to your TIFF file
ms_tiff_path = 'PAirMax/W3_Muni_Urb/FR/MS_LR.tif'
pan_tiff_path = 'PAirMax/W3_Muni_Urb/FR/PAN.tif'

# Read the TIFF image
ms = imageio.imread(ms_tiff_path)
pan = imageio.imread(pan_tiff_path)

pan = np.expand_dims(pan, -1)
# ms= np.transpose(ms, (0, 1, 2))

print(pan.shape,ms.shape)

# Set the figure size
fig, axes = plt.subplots(1, 2, figsize=(14, 7))  # Adjust the figsize as needed

# Display the first image
axes[0].imshow(pan[:, :], cmap='gray')  # Assuming the image is grayscale
axes[0].set_title('High Resolution Panchromatic Image')
axes[0].axis('off')

# Display the second image
axes[1].imshow(ms[:, :, 1], cmap='gray')  # Assuming the image is grayscale
axes[1].set_title('Low Resolution Multispectral Image')
axes[1].axis('off')

# Adjust layout to prevent overlapping
plt.tight_layout()

# Show the plot
plt.show()



# preprocess
# pan = np.expand_dims(pan, -1)
# ms= np.transpose(ms, (1, 2, 0))
```

```
max_patch, min_patch = np.max(ms, axis=(0,1)), np.min(ms, axis=(0,1))
ms = np.float32(ms-min_patch) / (max_patch - min_patch)
max_patch, min_patch = np.max(pan, axis=(0,1)), np.min(pan, axis=(0,1))
pan = np.float32(pan-min_patch) / (max_patch - min_patch)
```

```
(2048, 2048, 1) (512, 512, 8)
```



6 Apply Algorithm

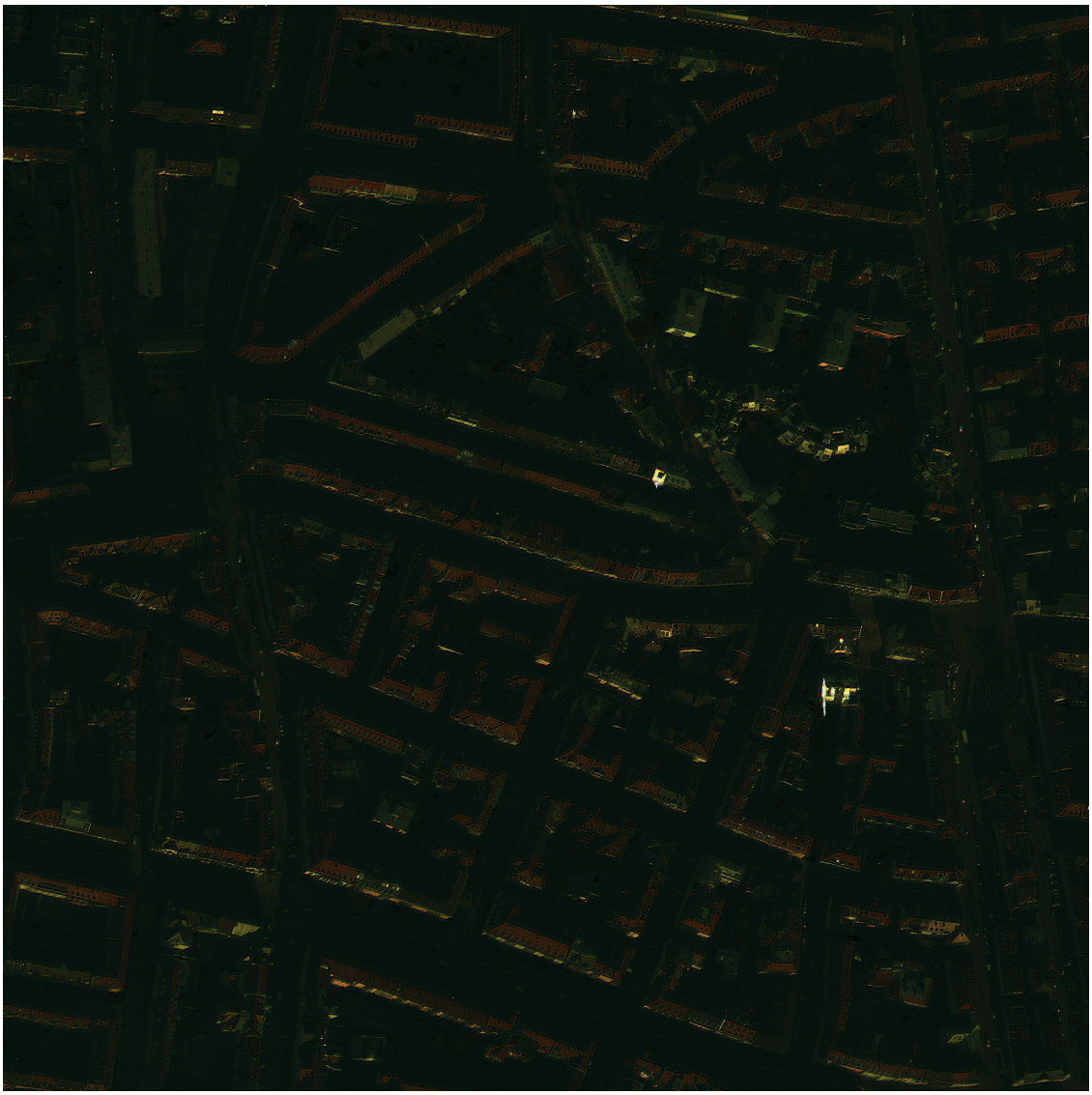
[5]:
```
fused_img = IHS(pan[:, :, :], ms[:, :, :])
print(pan.shape,ms.shape,fused_img.shape)

save_dir='./results/'
if not os.path.isdir(save_dir):
    os.makedirs(save_dir)

cv2.imwrite(save_dir+'IHS.tiff', fused_img[:, :, [0,1,3]])
```

```
get sharpening ratio:  4
(2048, 2048, 1) (512, 512, 8) (2048, 2048, 8)
```

[5]:
```
True
```

7 Print the Resulting Image

[6]:
```
# Specify the path to your TIFF image
image_path = 'results/IHS.tiff'

# Open the TIFF image using PIL
image = Image.open(image_path)

# Display the image in the Jupyter Notebook with a centered title
display(image)
display(HTML("<div style='text-align: center;'><h1>High Resolution␣
 ↪Multispectral Image</h1></div>"))
```



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

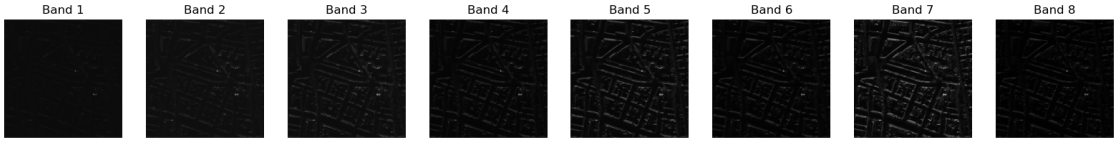
8 PSNR

- PSNR < 20 dB: Poor quality, significant loss of information.
- 20 dB $<$ PSNR < 30 dB: Fair quality, moderate loss of information.
- 30 dB $<$ PSNR < 40 dB: Good quality, acceptable for many applications.
- PSNR > 40 dB: Very good to excellent quality.

[7]:
```python
def psnr(img1, img2, dynamic_range=255):
    """PSNR metric, img uint8 if 225; uint16 if 2047"""
    if not  img1.shape == img2.shape:
        raise ValueError('Input images must have the same dimensions.')
    img1_ = img1.astype(np.float64)
    img2_ = img2.astype(np.float64)
    mse = np.mean((img1_ - img2_)**2)
    if mse <= 1e-10:
        return np.inf
    return 20 * np.log10(dynamic_range / (np.sqrt(mse) + np.finfo(np.float64).
 ↪eps))
```

9 Load Reference Image

[8]:
```python
import imageio
import matplotlib.pyplot as plt

# Specify the path to your TIFF image
reference_image_path = 'PAirMax/W3_Muni_Urb/FR/MS.tif'

# Read the TIFF image using imageio.v2
reference_image = imageio.v2.imread(reference_image_path)

# Get the number of bands in the image
num_bands = reference_image.shape[2]

# Display each band separately
fig, axes = plt.subplots(1, num_bands, figsize=(20, 5))

for i in range(num_bands):
    axes[i].imshow(reference_image[:, :, i], cmap='gray')
    axes[i].set_title(f'Band {i + 1}')
    axes[i].axis('off')

plt.show()
```



[9]:
```
# Normalization
max_patch, min_patch = np.max(reference_image, axis=(0,1)), np.
  ↪min(reference_image, axis=(0,1))
reference_image = np.float32(reference_image-min_patch) / (max_patch -␣
  ↪min_patch)
reference_image=np.uint8(reference_image*255)
```

[10]:
```
psnr(fused_img,reference_image)
```

[10]: 29.92626767165879