Question 1

a) Write a program to show the minimum and the maximum pixel values of an 8 bits/pixel grayscale image. Convert grayscale image to a binary image using threshold (Tth) operation where `Tth = (minimum pixel value + maximum pixel value) / 2`. Mathematically, `G(x, y) = 0 if f(x, y) ≤ (minimum gray value + maximum gray value) / 2; 1, otherwise`.

b) Do the same thresholding operation considering `Tth = 128`. `G(x, y) = 0 if f(x, y) ≤ 128; 1 otherwise`.

Highlight the differences in the two images obtained.

In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
```

Images to process

In [2]:
```
path_inp = '../../images/dat/'  # path for input files
path_out_orig = 'originals/'    # path for output files: originals
path_out_conv = 'converted/'    # path for output files: converted

filenames = [
    'b256',
    'ba256',
    'f256',
    'l256',
    'n256',
    'o256',
    'p256',
    'pap256',
    'z256'
]

ext_inp = '.dat'    # file extention for input
ext_out = '.bmp'    # file extention for output
```

Convert images to numpy array and store in a list of tuples as (filename, np.array)

In [3]:
```
# Stores the list of (filename, image) tuples for the images
images = []

# Iterate for all filenames
for idx, filename in enumerate(filenames):
    # Store image pixels as uint8 2D array
    image = np.array(
        [i.strip().split() for i in open(path_inp + filename + ext_inp).readlines()],
        dtype='uint8'
    )

    # Add (filename, numpy array of image) into images list
    images.append((filename, image))

    # Save original image as .dat file
    np.savetxt(
        path_out_orig + ext_inp[1:] + '/' + filename + ext_inp,
        image,
        fmt=' %d',
        newline=' \n'
    )
```

Display input images

In [4]:
```
# Matrix dimensions
cols = 3
rows = -(-len(filenames) // cols)

# Create figure with rows × cols subplots
fig, axs = plt.subplots(rows, cols, dpi=80, sharex=True, sharey=True)
fig.set_size_inches(4 * cols, 4.5 * rows)

# Iterate for all images
for idx, (filename, image) in enumerate(images):
    # Set subplot title as '"filename" (rows, cols)'
    axs[int(idx // cols), idx % cols].set_title('"{}" {}'.format(
        filename + ext_inp,
        image.shape
    ))
    # Add subplot to figure plot buffer
    axs[int(idx // cols), idx % cols].imshow(
        image,
        cmap='gray',
        vmin=0,
        vmax=255
    )

    # Save original image as .bmp file
```

```
    plt.imsave(
        path_out_orig + ext_out[1:] + '/' + filename + ext_out,
        image,
        cmap='gray',
        vmin=0,
        vmax=255
    )

# Hide x labels and tick labels for top plots and y ticks for right plots
for ax in axs.flat:
    ax.label_outer()

# Display the figure
plt.show()
```

In [5]:

```
# Store the threshold images
thres_imgs = []
```

Section (a)

Display the maximum and minimum pixel values of each image.

Convert grayscale image to a binary image using threshold (Tth) operation where

`Tth = (minimum pixel value + maximum pixel value) / 2` .

Mathematically, `G(x, y) = 0 if f(x, y) ≤ (minimum gray value + maximum gray value) / 2; 1, otherwise` .

In [6]:
```
# Create figure with rows × cols subplots
fig, axs = plt.subplots(rows, cols, dpi=80, sharex=True, sharey=True)
fig.set_size_inches(4 * cols, 4.5 * rows)
fig.suptitle("Threshold: average(min, max)", fontsize=18)

# Iterate for all images
for idx, (filename, image) in enumerate(images):
    # print('Image: "{}"\n'.format(filename))

    min_pixel = min([min(i) for i in image])    # minimum pixel value
    max_pixel = max([max(i) for i in image])    # maximum pixel value

    # print('Mininum pixel value: {}'.format(min_pixel))
    # print('Maximum pixel value: {}'.format(max_pixel))

    threshold = (int(min_pixel) + int(max_pixel)) // 2  # threshold
    # print('Threshold: {}'.format(threshold))

    '''
    Threshold image.

    Create a binary matrix of same shape as image.
    Each value is whether corresponding pixel value is higher than threshold.
    '''
    thres_img = (image > threshold) * 1

    # Add dictionary of filename, min pixel, max pixel, threshold image into list
    thres_imgs.append({
        'filename': filename,
        'threshold': threshold,
        'thres_avg': thres_img
    })

    # Set subplot title
    axs[int(idx // cols), idx % cols].set_title(
        'image: "{}"\npixel range: [{} - {}]\nthreshold: {}'.format(
            filename,
            min_pixel,
            max_pixel,
            threshold
        )
    )
    # Add subplot to figure plot buffer
    axs[int(idx // cols), idx % cols].imshow(
        thres_img,
        cmap='gray',
        vmin=0,
        vmax=1
    )

    # Save threshold image as .bmp file
    plt.imsave(
        path_out_conv + ext_out[1:] + '/' + filename + '_thres_avg' + ext_out,
        thres_img,
        cmap='gray',
        vmin=0,
        vmax=1
    )

    # Save pixel values of threshold image as a 2D matrix in a .dat file
    np.savetxt(
        path_out_conv + ext_inp[1:] + '/' + filename + '_thres_avg' + ext_inp,
        thres_img,
        fmt=' %d',
        newline=' \n'
    )

# Hide x labels and tick labels for top plots and y ticks for right plots
for ax in axs.flat:
    ax.label_outer()

# Save and display the figure
plt.savefig('threshold_avg.jpg')
plt.show()
```

Section (b)

Do the same thresholding operation considering `Tth = 128` .

```
G(x, y) = 0 if f(x, y) ≤ 128; 1 otherwise
```

In [7]:

```
# Create figure with rows × cols subplots
fig, axs = plt.subplots(rows, cols, dpi=80, sharex=True, sharey=True)
fig.set_size_inches(4 * cols, 4.5 * rows)
fig.suptitle("Threshold: 128", fontsize=18)

# Iterate for all images
for idx, (filename, image) in enumerate(images):
    threshold = 128

    '''
    Threshold image.

    Create a binary matrix of same shape as image.
    Each value is whether corresponding pixel value is higher than threshold.
```

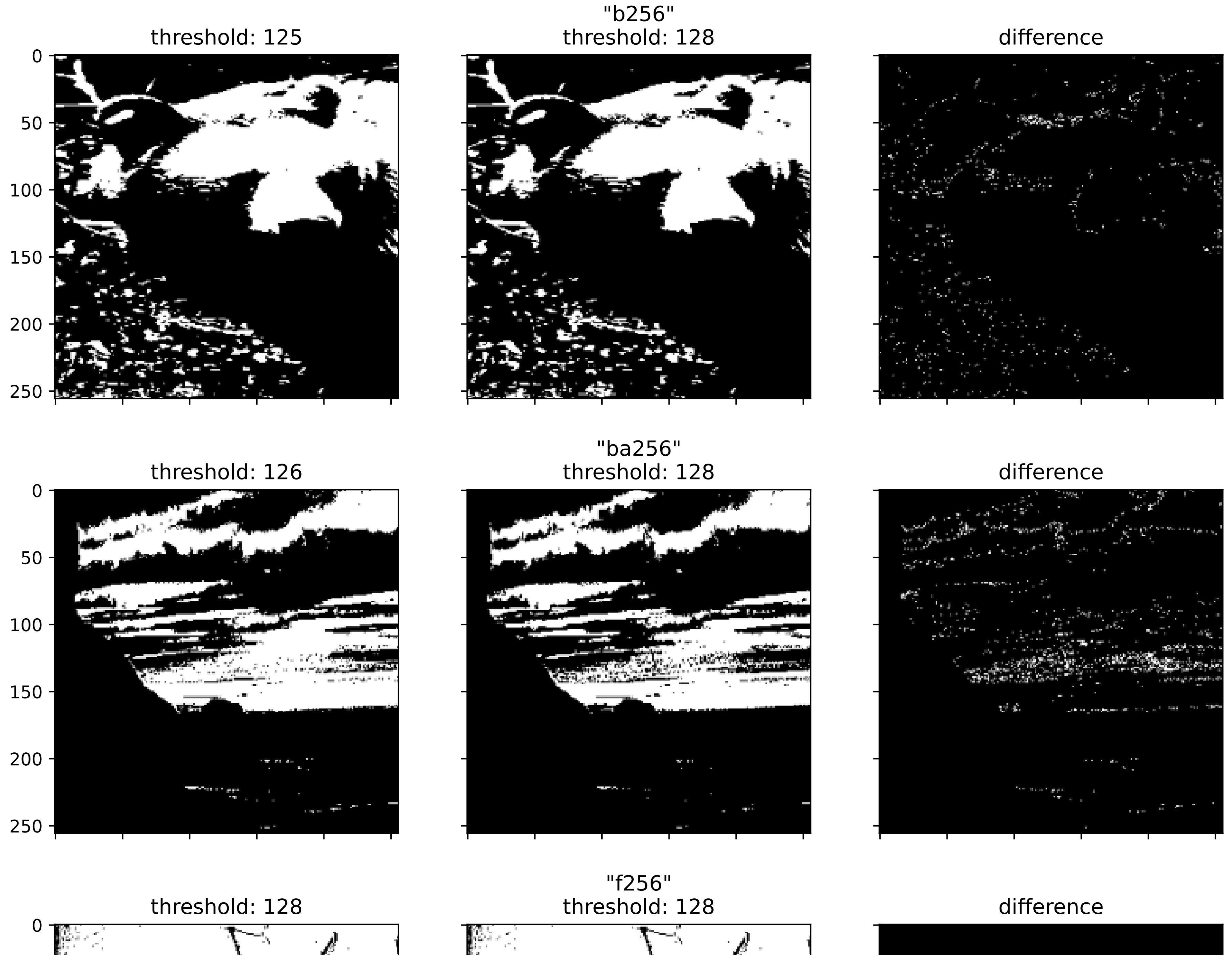
```
    '''
    thres_img = (image > threshold) * 1

    # Add threshold image to corresponding dictionary in list of threshold images
    thres_imgs[idx]['thres_128'] = thres_img

    # Set subplot title
    axs[int(idx // cols), idx % cols].set_title(
        'image: "{}"\npixel range: [{} - {}]'.format(
            filename,
            min_pixel,
            max_pixel
        )
    )
    # Add subplot to figure plot buffer
    axs[int(idx // cols), idx % cols].imshow(
        thres_img,
        cmap='gray',
        vmin=0,
        vmax=1
    )

    # Save threshold image as .bmp file
    plt.imsave(
        path_out_conv + ext_out[1:] + '/' + filename + '_thres_128' + ext_out,
        thres_img,
        cmap='gray',
        vmin=0,
        vmax=1
    )

    # Save pixel values of threshold image as a 2D matrix in a .dat file
    np.savetxt(
        path_out_conv + ext_inp[1:] + '/' + filename + '_thres_128' + ext_inp,
        thres_img,
        fmt=' %d',
        newline=' \n'
    )

# Hide x labels and tick labels for top plots and y ticks for right plots
for ax in axs.flat:
    ax.label_outer()

# Save and display the figure
plt.savefig('threshold_128.jpg')
plt.show()
```

Compare images

In [8]:

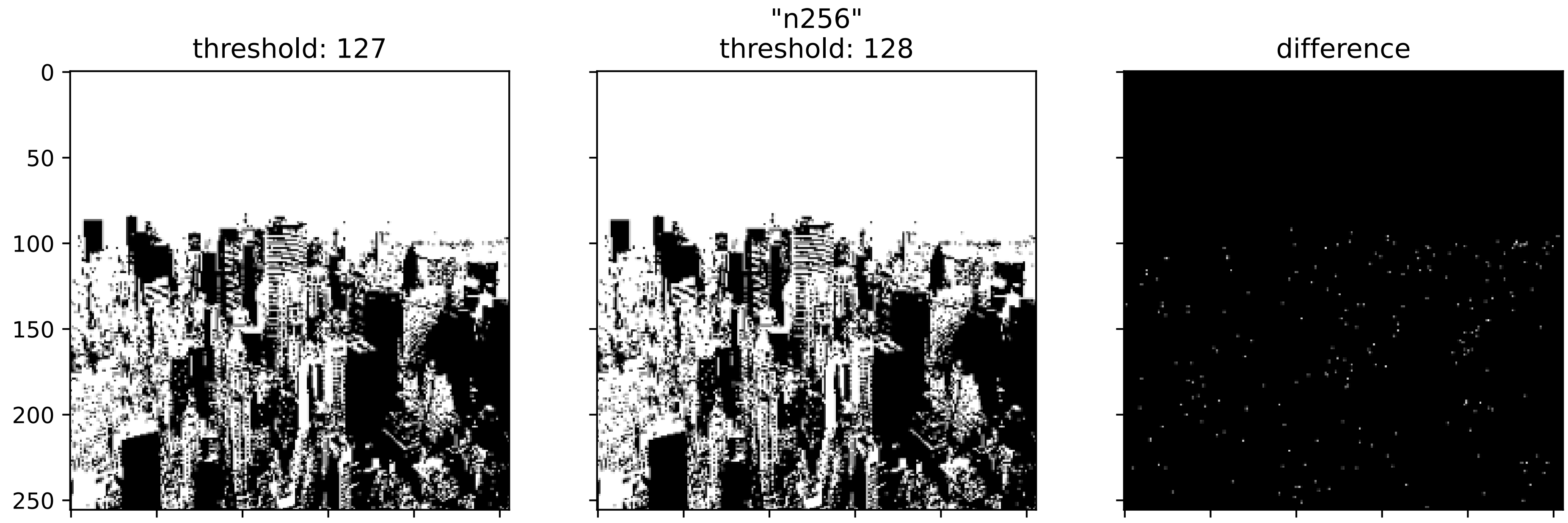
```
rows = len(thres_imgs)
cols = 3

# Create figure with len(thres_imgs) × 2 subplots
fig, axs = plt.subplots(rows, cols, dpi=80, sharex=True, sharey=True)
fig.set_size_inches(4 * cols, 4.5 * rows)

# Iterate for all threshold images
for idx, img_dict in enumerate(thres_imgs):
    # Generate binary difference matrix
    diff = abs(img_dict['thres_avg'] - img_dict['thres_128'])
    diff = 1 - ((diff == 0) * 1)

    # Set subplot title as 'threshold: $avg_value'
    axs[idx, 0].set_title('threshold: {}'.format(img_dict['threshold']))
    # Add subplot to figure plot buffer
    axs[idx, 0].imshow(
        img_dict['thres_avg'],
        cmap='gray',
```

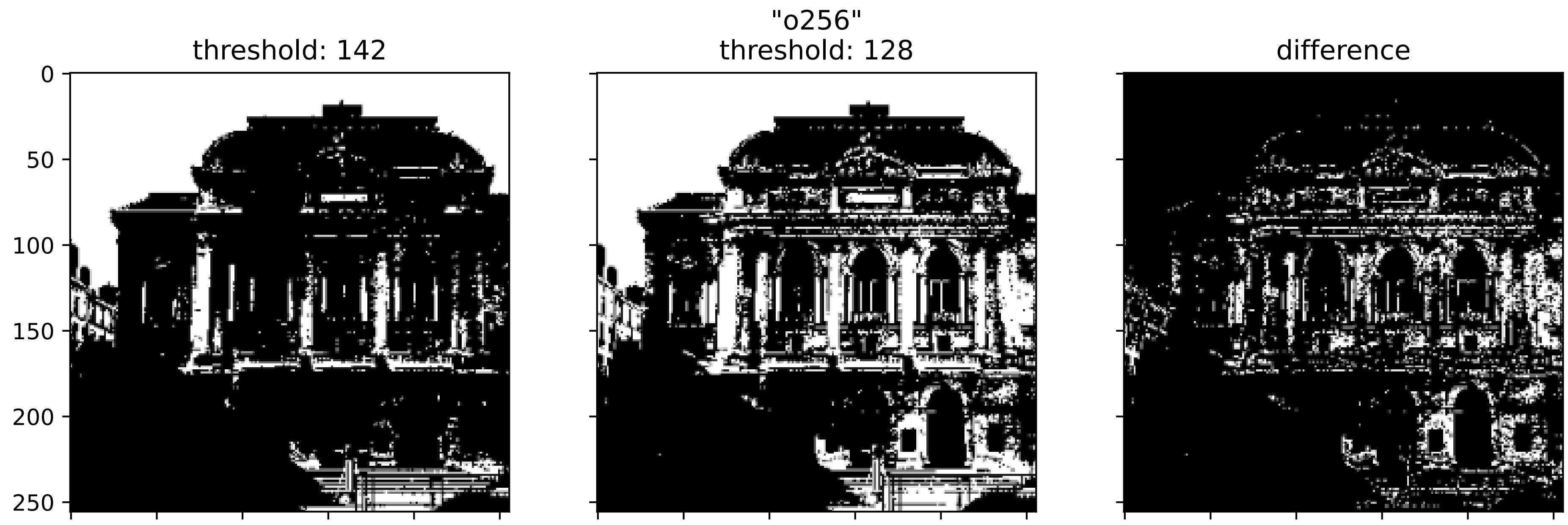
```
        vmin=0,
        vmax=1
    )
    # Set subplot title as 'threshold: 128'
    axs[idx, 1].set_title('{}\nthreshold: 128'.format(
        '"{}"'.format(img_dict['filename'])
    ))
    # Add subplot to figure plot buffer
    axs[idx, 1].imshow(
        img_dict['thres_128'],
        cmap='gray',
        vmin=0,
        vmax=1
    )
    # Set subplot title as '"filename" (rows, cols)'
    axs[idx, 2].set_title('difference')
    # Add subplot to figure plot buffer
    axs[idx, 2].imshow(
        diff,
        cmap='gray',
        vmin=0,
        vmax=1
    )

    # Save difference image as .bmp file
    plt.imsave(
        path_out_conv + ext_out[1:] + '/' + img_dict['filename'] + '_diff' + ext_out,
        diff,
        cmap='gray',
        vmin=0,
        vmax=1
    )

    # Save pixel values of difference image as a 2D matrix in a .dat file
    np.savetxt(
        path_out_conv + ext_inp[1:] + '/' + img_dict['filename'] + '_diff' + ext_inp,
        diff,
        fmt=' %d',
        newline=' \n'
    )

# Hide x labels and tick labels for top plots and y ticks for right plots
for ax in axs.flat:
    ax.label_outer()

# Save and display the figure
plt.savefig('difference.jpg')
plt.show()
```

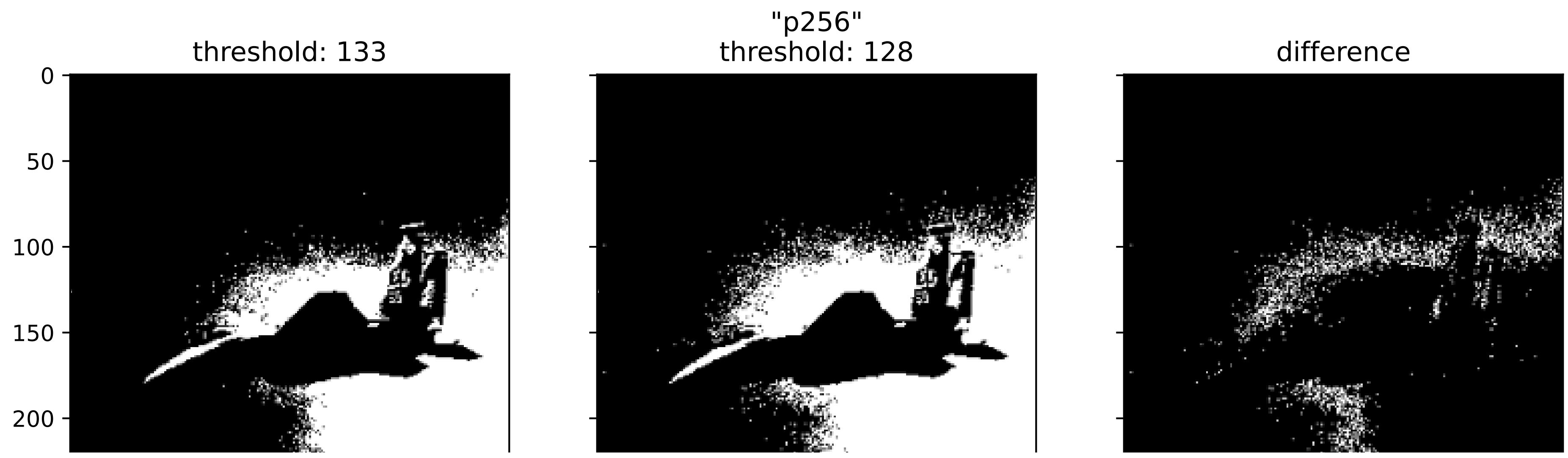


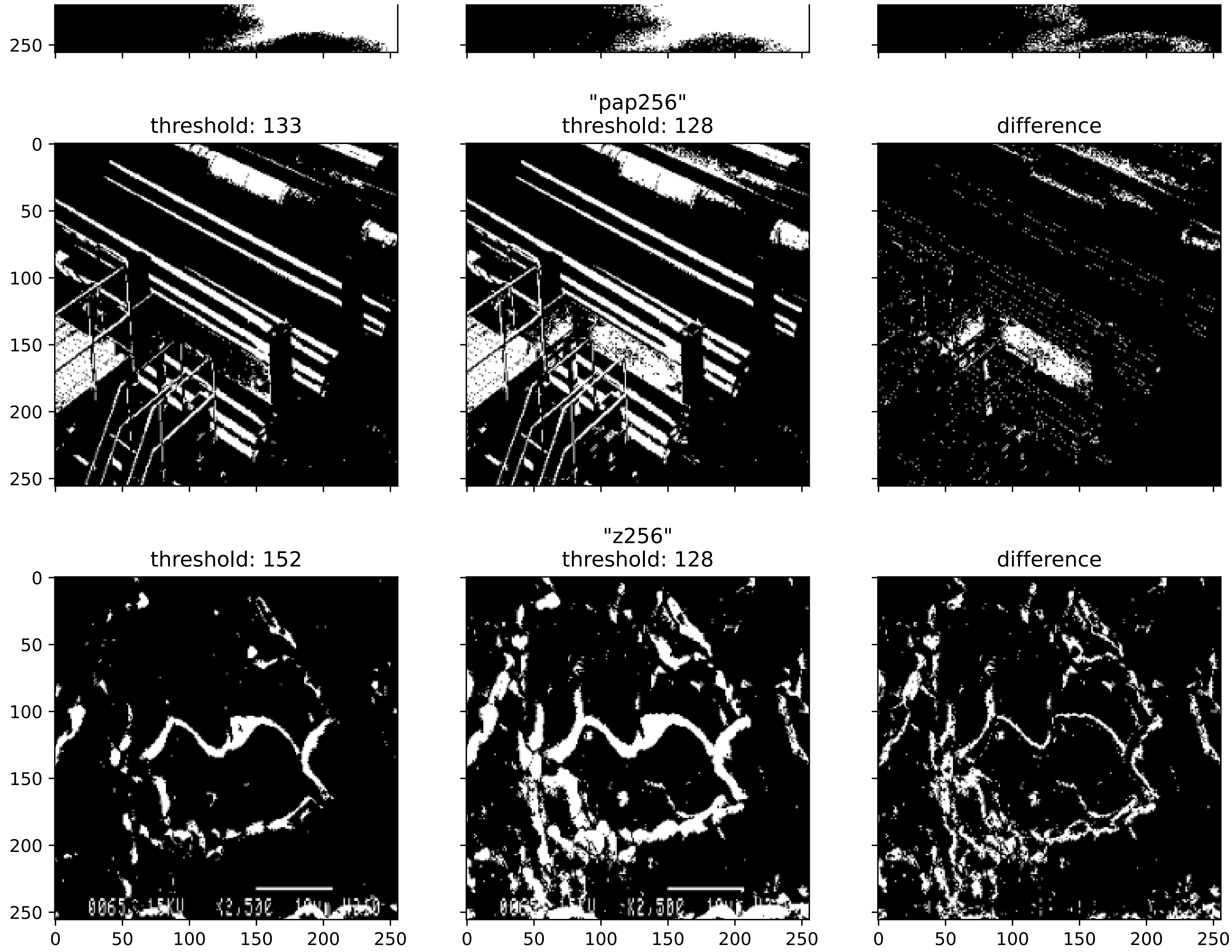

50
100
150
200
250


"l256"
threshold: 133
threshold: 128
difference
0
50
100
150
200
250


"n256"
threshold: 127
threshold: 128
difference
0
50
100
150
200
250


"o256"
threshold: 142
threshold: 128
difference
0
50
100
150
200
250


"p256"
threshold: 133
threshold: 128
difference
0
50
100
150
200



Resource

GitHub repository: `Image Processing and Pattern Recognition - Anindya Kundu (meganindya)`