Technische Universität München
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Exercises in Photogrammetry, Remote Sensing, and Image Processing

Name, Given name:

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Exercise number.: 1

Topic: Image Characteristics

Study Program: ESPACE

(filled in by supervisor)

Date: _____

Points: _____

Supervisor: _____

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1 Image Characteristics

1.1 Image Histogram

The histogram of an image can be computed by counting the number of pixels with each intensity value. The histogram of an image can be used to get an idea of the contrast of the image, the dynamic range of the intensity values, and the brightness of the image.

```
hist = np.zeros(256)
for i in range(img.shape[0]):
  for j in range(img.shape[1]):
    hist[img[i,j]] += 1
```

The code iterates through the image and counts the number of pixels with each intensity value. The result is shown in Figure 1.

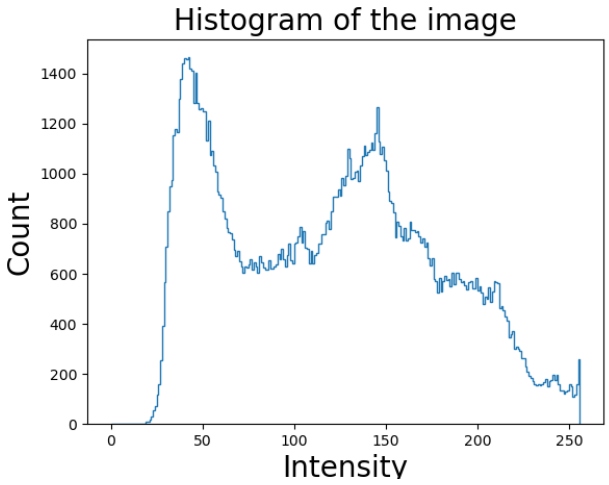


Figure 1: Histogram of the image

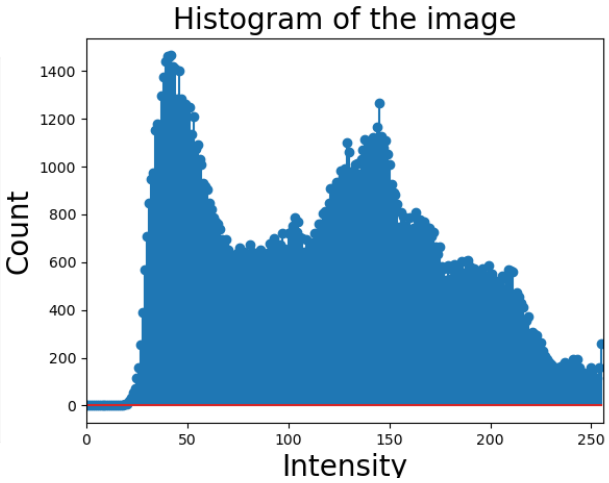


Figure 2: Check the histogram using plt.stem()

1.2 mean, variance, and standard deviation

The mean, variance, and standard deviation of an image can be computed by the following equations:

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i$$

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2$$

$$\sigma = \sqrt{\sigma^2}$$

Implementing the equations in Python:

```
mean = np.sum(img)/np.size(img)
var = np.sum((img-mean)**2)/np.size(img)
std = np.sqrt(var)
```

The results are shown below and checked with numpy functions.

```
mean =  118.41953125
np.mean =  118.41953125
var =  3413.9199622802735
np.var =  3413.9199622802735
std =  58.42875971882574
np.std =  58.42875971882574
```

2 Correlation coefficient

The correlation coefficient and covariance of two images can be computed by the following equation:

$$\sigma_{xy} = \frac{1}{N}\sum_{i=1}^{N}(x_i - \mu_x)(y_i - \mu_y)$$

$$\rho = \frac{\sum_{i=1}^{N}(x_i - \mu_x)(y_i - \mu_y)}{\sqrt{\sum_{i=1}^{N}(x_i - \mu_x)^2}\sqrt{\sum_{i=1}^{N}(y_i - \mu_y)^2}}$$

$$= \frac{\sum_{i=1}^{N} x_i y_i - N\mu_x\mu_y}{\sqrt{\sum_{i=1}^{N} x_i^2 - N\mu_x^2}\sqrt{\sum_{i=1}^{N} y_i^2 - N\mu_y^2}}$$

Implementing the equations in Python:

```
def cov(img1, img2):
    cov = np.zeros((img1.shape[0], img1.shape[1]))
    cov=
       np.sum((img1-np.mean(img1))*(img2-np.mean(img2)))/np.size(img1)
    return cov

corr = cov(img1,img2)/(np.std(img1)*np.std(img2))
```

The results are shown below and checked with numpy functions.

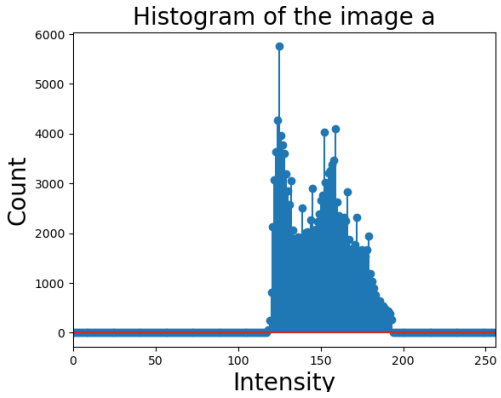
```
cov =  -1084.5263637597654
np.cov =  -1084.5331420919058
corr =  -0.9998783738444597
np.corrcoef =  -0.9998783738444569
```

We can see there is a very slight numerical difference in covariances.

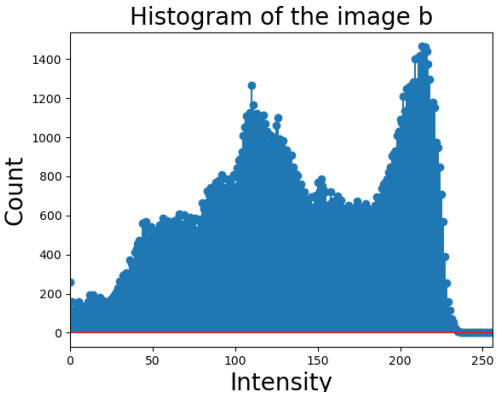
3 Test images

3.1 Histogram, mean, variance, and standard deviation

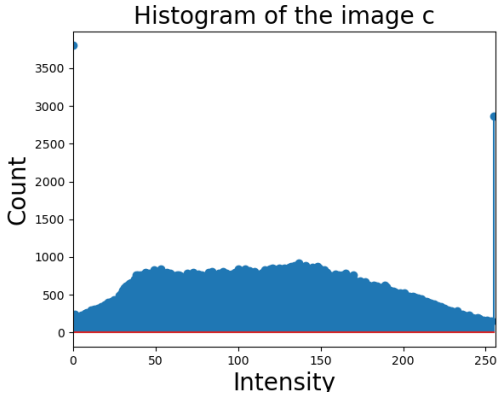
In this task we are going to compute the histograms, mean, variance, and standard deviation of the test images. The results are shown below.



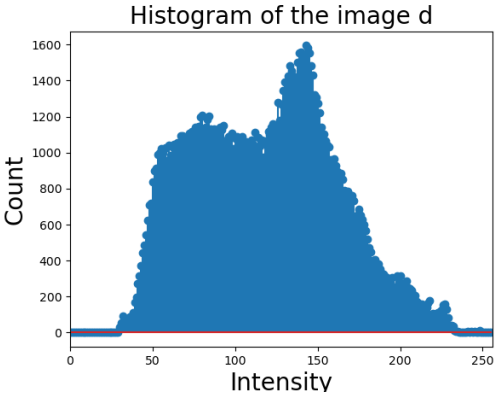
a) Image a



b) Image b



c) Image c



d) Image d

By observing the histograms we can see that the image a has a lower contrast than the original image and the image b is the inverted image. The grey values of the image c are more evenly distributed than the original image, which tells that this image has a lot of noises and the image d has a similar histogram to the original image.

```
Image  images/image_a.bmp :
mean =  149.1242875
var =  344.61370261734373
std =  18.56377393251016
Image  images/image_b.bmp :
mean =  136.58046875
var =  3413.9199622802735
std =  58.42875971882574
Image  images/image_c.bmp :
mean =  118.48776875
```

```
var =  4196.281325396523
std =  64.7787104332629
Image  images/image_d.bmp :
mean =  117.9137875
var =  1840.1958299048438
std =  42.89750377242065
```

The standard deviation of the image a is the smallest and the standard deviation of the image c is the largest. The variance of the image b is the largest and the variance of the image a is the smallest. The mean of the image b is the largest and the mean of the image a is the smallest. This also stands for that the image a has the lowest contrast.

3.2 Corvariance and correlation coefficient

In this task we are going to compute the covariance and correlation coefficient of the test images. The results are shown below.

```
Image  images/image_a.bmp :
cov =  1084.5263637597654
corr =  0.9998783738444597
Image  images/image_b.bmp :
cov =  -3413.9199622802735
corr =  -1.0000000000000002
Image  images/image_c.bmp :
cov =  3343.296459516602
corr =  0.8833156452953814
Image  images/image_d.bmp :
cov =  2145.6104938378908
corr =  0.8560363290240045
```

The correlation coefficient demenstrates how similar the two compared images and the range of the correlation coefficient lies between 1 to -1. The 1 stands for the two images are identical and the -1 stands for the two images are completely different. The covariance is the measure of how much two random variables change together. The positive covariance means the two variables are positively related and the negative covariance means the two variables are negatively related.

So we can summerize the results that the image a, c and d are very similar to the original image and the image b is the inverted image.

4 Template search

In this task we are going to find the template in the image using the correlation coefficient. The results are shown below.

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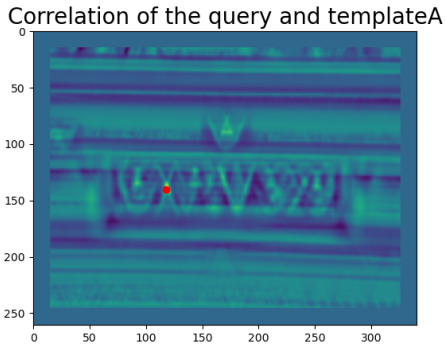
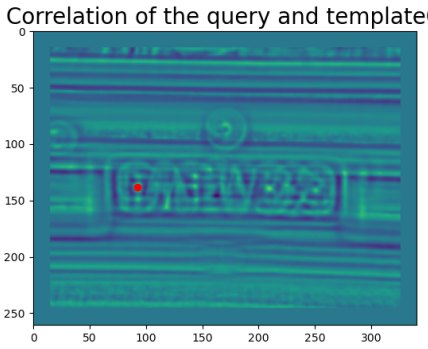
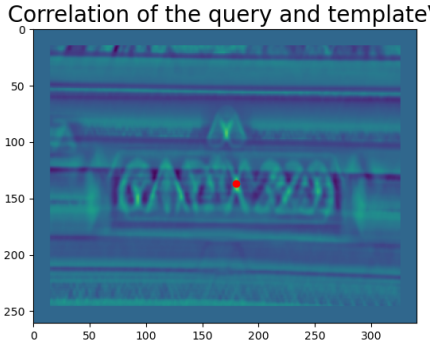


a) Search on A

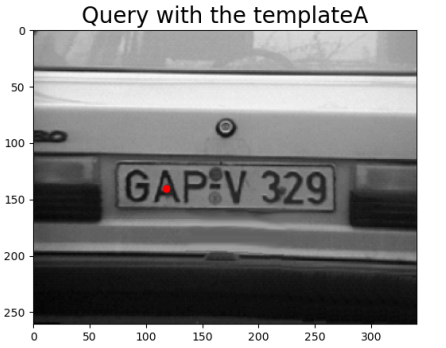


b) Search on G

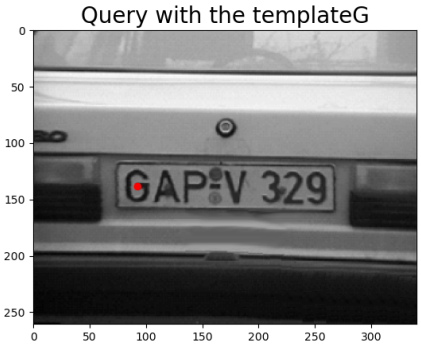
c) Search on P



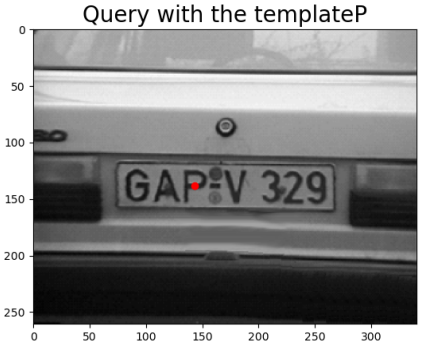
d) Search on V



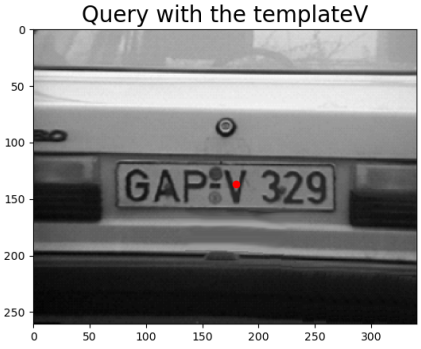
a) Search on A



b) Search on G



c) Search on P



d) Search on V

The principle of a template search is to find the most similar part of the image to the template. The correlation coefficient is used to measure the similarity between the template and the image. The template is sliding over the whole image and the correlation coefficient is computed at each position. The position with the highest correlation coefficient is the most similar part of the image to the template. We can see that all letters are identified sucessfully in the query imagery.

Code

```python
# PRE-T 01: Image Characteristics
# Hsin-Feng Ho 03770686
import os
import numpy as np
import matplotlib.pyplot as plt
import IP01_function as IP

# load the image
plt.figure()
img = plt.imread('images/image.bmp')
#  print(img.shape)
#  print(img)
#plt.imshow(img)

# calculate the histogram
hist = np.zeros(256)
for i in range(img.shape[0]):
    for j in range(img.shape[1]):
        hist[img[i,j]] += 1

# plot the histogram
plt.figure()
plt.stairs(hist)
plt.xlabel('Intensity', fontsize=20)
plt.ylabel('Count', fontsize=20)
plt.title('Histogram of the image', fontsize=20)
# save the plot
#plt.savefig('histogram.png')
# check the histogram
plt.figure()
plt.stem(range(256), hist)  # Using plt.stem() instead of
   plt.hist()
plt.xlim([0,256])
plt.title('Histogram of the image', fontsize=20)
plt.xlabel('Intensity', fontsize=20)
plt.ylabel('Count', fontsize=20)
# save the plot
#plt.savefig('histogram_check.png')

# calculate the mean of the image
mean = np.sum(img)/np.size(img)
print('mean = ', mean)
print('np.mean = ', np.mean(img))

# calculate the variance of the image
var = np.sum((img-mean)**2)/np.size(img)
print('var = ', var)
print('np.var = ', np.var(img))

```

```
49 # calculate the standard deviation of the image
50 std = np.sqrt(var)
51 print('std = ', std)
52 print('np.std = ', np.std(img))
53
54 # calculate the covariance of the image
55 def cov(img1, img2):
56     cov = np.zeros((img1.shape[0], img1.shape[1]))
57     cov=
          np.sum((img1-np.mean(img1))*(img2-np.mean(img2)))/np.size(img1)
58     return cov
59
60 img1=plt.imread('images/image_a.bmp')
61 img2=plt.imread('images/image_b.bmp')
62 print('cov = ', cov(img1, img2))
63 print('np.cov = ', np.cov(img1.reshape((1,-1)),
      img2.reshape((1,-1)))[0,1])
64
65 # calculate the correlation coefficient of the image
66 corr = cov(img1,img2)/(np.std(img1)*np.std(img2))
67 print('corr = ', corr)
68 print('np.corrcoef = ', np.corrcoef(img1.reshape((1,-1)),
      img2.reshape((1,-1)))[0,1])
69
70 def testImage(img):
71     # calculate the histogram
72     hist, bins = np.histogram(img.flatten(), 256, [0,256])
73     # calculate the mean
74     mean = np.mean(img)
75     # calculate the variance
76     var = np.var(img)
77     # calculate the standard deviation
78     std = np.std(img)
79     return hist, mean, var, std
80
81 # load the images
82 test_img=['images/image_a.bmp', 'images/image_b.bmp',
      'images/image_c.bmp', 'images/image_d.bmp']
83 a=['a', 'b', 'c', 'd']
84 for i in range(len(test_img)):
85     img_t = plt.imread(test_img[i])
86     hist, mean, var, std = testImage(img_t)
87     print('Image ', test_img[i], ':')
88     print('mean = ', mean)
89     print('var = ', var)
90     print('std = ', std)
91     plt.figure()
92     plt.stem(range(256), hist)
93     plt.xlim([0,256])
94     plt.title('Histogram of the image '+a[i], fontsize=20)
95     plt.xlabel('Intensity', fontsize=20)
```

```
96      plt.ylabel('Count', fontsize=20)
97      plt.savefig('histogram_check'+str(i)+'.png')
98  for i in range(len(test_img)):
99      img_t = plt.imread(test_img[i])
100     sigma=cov(img, img_t)
101     rho = sigma/(np.std(img)*np.std(img_t))
102     print('Image ', test_img[i], ':')
103     print('cov = ', sigma)
104     print('corr = ', rho)
105
106 # Template search
107 # load the image
108 query = plt.imread('images/query.bmp')
109 def templateSearch(img, query):
110     # return the most likely position of a template in the
            original image
111     return IP.getMaximumCorrPoint(IP.correlation(img, query))
112 temp_list=['images/templateA.bmp', 'images/templateG.bmp',
        'images/templateP.bmp', 'images/templateV.bmp']
113 alphabet = ['A', 'G', 'P', 'V']
114 for i in range(len(temp_list)):
115     temp = plt.imread(temp_list[i])
116     position = templateSearch(query, temp)
117     print('templateSearch' +alphabet[i]+'= ', position)
118     plt.figure()
119     plt.imshow(IP.correlation(query, temp))
120     plt.scatter(position[1], position[0], color='r')
121     plt.title('Correlation of the query and template'+alphabet[i],
            fontsize=20)
122     #plt.savefig('correlation'+alphabet[i]+'.png')
123     plt.figure()
124     plt.imshow(query,cmap='gray')
125     plt.scatter(position[1], position[0], color='r')
126     plt.title('Query with the template'+alphabet[i], fontsize=20)
127     #plt.savefig('query'+alphabet[i]+'.png')
128
129 plt.show()
```