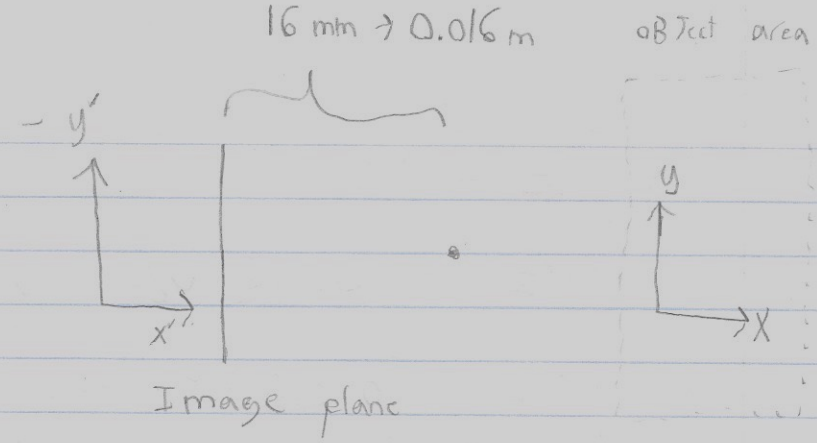
1



a) $(X, y, z) = (2, 3, 4)$

$x' = f \cdot X/z = 0.016 \cdot 2/4 = 0.008$ m

$y' = f \cdot y/z = 0.016 \cdot 3/4 = 0.012$ m

$[0.008, 0.012, 0]$ m

b) $x, y, z = 4, 6, 8$

$x' = f \cdot x/z = 0.016 \cdot 4/8 = 0.008$ m

$y' = f \cdot y/z = 0.016 \cdot 6/8 = 0.012$ m

$[0.008, 0.012, 0]$

c) $X, y, z = -1, -2, 8$

$x' = f \cdot X/z = .016 \cdot -1/8 = -.002$

$y' = f \cdot y/z = .016 \cdot -2/8 = -.004$

$[-.002, -.004, 0]$

d) $X, Y, Z = 0, 0, 4$

$x' = f \cdot x/z = 0.016 \cdot 0/4 = 0$

$y' = f \cdot y/z = 0.016 \cdot 0/4 = 0$

$[0, 0, 0]$

e $\bar{A} = \begin{bmatrix} 0 \\ 0 \\ 4 \end{bmatrix}$ $A' = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

$\bar{B} = \begin{bmatrix} 2 \\ 3 \\ 4 \end{bmatrix}$ $B' = .016/4 \cdot \begin{bmatrix} 2 \\ 3 \\ 0 \end{bmatrix} = \begin{bmatrix} .008 \\ 0.012 \\ 0 \end{bmatrix}$

$A' - B' = \begin{bmatrix} -.008 \\ -.012 \\ 0 \end{bmatrix}$ $\|A' - B'\| = \sqrt{.008^2 + .012^2} = .0144\text{m}$

f $\bar{A} = \begin{bmatrix} 0 \\ 0 \\ 4 \end{bmatrix}$ $A' = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

$\bar{B} = \begin{bmatrix} 4 \\ 6 \\ 8 \end{bmatrix}$ $B' = .016/8 \cdot \begin{bmatrix} 4 \\ 6 \\ 0 \end{bmatrix} = \begin{bmatrix} .008 \\ .012 \\ 0 \end{bmatrix}$

$\|A' - B'\| = .0144\text{m}$

2 let $\vec{N}$ Be the vector made up of the Distance Between $N_{Head} = \begin{bmatrix} H_x \\ H_y \end{bmatrix}$ and $N_{Tail} \begin{bmatrix} T_x \\ T_y \end{bmatrix}$

Where H_x and H_y are the Cordinates of the Nail Head and T_x, T_y are the Cordinates of the Nail tail., Such that

$$\vec{N} = \begin{bmatrix} T_x \\ T_y \end{bmatrix} - \begin{bmatrix} H_x \\ H_y \end{bmatrix} = N_T - N_H = \begin{bmatrix} \Delta X \\ \Delta y \end{bmatrix}$$

Because the nail Does not change size $||\vec{N}||$ is Constant

Because the table is flat and parrallel to the image plane We may represent Cordinates in the image plane as a Scaling transform as Shown Below

$$T = \begin{bmatrix} f/z_c & 0 & 0 \\ 0 & f/z_c & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Thus the projection of $\vec{N}$ onto the image plane is $T \cdot \vec{N}$

$$\begin{bmatrix} f/z_c & 0 & 0 \\ 0 & f/z_c & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \Delta X \\ \Delta y \\ 0 \end{bmatrix} = f/z_c \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & z/f \end{bmatrix} \cdot \begin{bmatrix} \Delta X \\ \Delta y \\ 0 \end{bmatrix}$$

$\xi_c/z \cdot \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix}$

Again the norm of $\begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix}$ or $\|\vec{N}\|$ is Constant as the length of the nail Does not Change

ξ_c/z is Constant

Constant X Constant = Constant

3 $g = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$ $h = \begin{bmatrix} 1 & -1 \\ 2 & -2 \end{bmatrix}$

$(I * g) * h = I * f$ associative So:

$I * (g * h) = (I * g) * h = I * f$

$f = g * h$

flip h and use correlation

$h' = \begin{matrix} -2 & 2 \\ -1 & 1 \end{matrix}$

$g \otimes h'$:

$\begin{bmatrix} 1 & 2 \\ -2 & 2 \\ 3 & 4 \\ -1 & 1 \end{bmatrix} = -2 + 4 - 3 + 4 = 3 \quad \begin{bmatrix} 3 \end{bmatrix}$

$\begin{bmatrix} 1 & 2 \\ -2 & 2 \\ 3 & 4 \\ -1 & 1 \end{bmatrix} = -4 + -4 = -8 \quad \begin{bmatrix} 3 & -8 \end{bmatrix}$

$\begin{bmatrix} 1 & 2 \\ -2 & 2 \\ 3 & 4 \\ -1 & 1 \end{bmatrix} = -6 + 8 = 2 \quad \begin{bmatrix} 3 & -8 \\ 2 & \end{bmatrix}$

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \quad 2 \quad -1 \quad 1$$

$= -8$ $\begin{bmatrix} 3 & -8 \\ 2 & -8 \end{bmatrix}$

$g * h = 5 =$ $\begin{bmatrix} 3 & -8 \\ 2 & -8 \end{bmatrix}$

4 in General we may write the location of any point in the image plane with the following

$$x' = f \cdot X/Z$$

$$y' = f \cdot y/Z$$

$$Z' = 0$$

it is Given that:

$$X = at + X_0$$
$$y = bt + y_0$$
$$z = Ct + Z_0$$

Because Z' is Constant [image plane perpendicular to Z axis] and taken to be 0 for simplicity We can assume the line is in the X', y' plane. This means that the equation of a line will be a linear Combination of X' and y'

Suppose now we have 2 line L_1 and L_2

$$\vec{L}_1 = \begin{matrix} at + X_0 \\ bt + y_1 \\ Ct + Z_1 \end{matrix} \quad \text{and} \quad L_2 = \begin{matrix} at + X_2 \\ bt + y_2 \\ Ct + Z_2 \end{matrix}$$

Such that $\vec{L}_1 \parallel \vec{L}_2$

if Howeve we examine these lines in the image plane

We can see that they will intersect.

any X Cordinate on $\vec{L_1}$ and $\vec{L_2}$ can be mapped to the image plane via:

$X' = fX/Z$ So

X' for $\vec{L_1}$ is $f(at + X_1)/Z = f(at + X_1)/(Ct + Z_1)$

X' for L_2 is $f(at + X_2)/(Ct + Z_2)$

We want to find the intersection point So set them equal

$$X'_{L1} = X'_{L2} \rightarrow \frac{f(at + X_1)}{(Ct + Z_1)} = \frac{f(at + X_2)}{(Ct + Z_2)}$$

if we take $\lim_{t \to \infty}$ we see the X Cordinates are equal and find the X Cordinate of the Vanishing point

$$\lim_{t \to \infty} \frac{f(at + X_1)}{(Ct + Z_1)} = \lim_{t \to \infty} \frac{f(at + X_1)\, d/dt}{(Ct + Z_1)\, d/dt} = \lim_{t \to \infty} \frac{fa}{C} = \frac{fa}{C}$$

$$\lim_{t \to \infty} \frac{f(at + X_2)}{(Ct + Z_2)} = \lim_{t \to \infty} \frac{f(at + X_1)\, d/dt}{(Ct + Z_1)\, d/dt} = \lim_{t \to \infty} \frac{fa}{C} = \frac{fa}{C}$$

$\therefore$

if we use the same process we can show that y cordinates are equal

$$y' = f \cdot y/z$$

y' for $\vec{L}_1$ is $f(bt + y_1)/(ct + z_1)$
y' for $\vec{L}_2$ is $f(bt + y_2)/(ct + z_2)$

again we want to find the intersection so we set them equal

$$y'_{L1} = y'_{L2} \rightarrow \frac{f(bt + y_1)}{ct + z_2} = \frac{f(bt + y_2)}{ct + z_2}$$

if we take the limit $t \to \infty$ we see the y cordinates are equal and we solve for the y cordinate of the vanising point.

$$\lim_{t \to \infty} \frac{f(bt + y_1)}{ct + z_2} = \frac{fb}{c}$$

$$\lim_{t \to \infty} \frac{f(bt + y_1)}{ct + z_2} = \frac{fb}{c}$$

So the Vanishing point in the image plane is

$$\boxed{\frac{fa}{c}, \frac{fb}{c}, 0}$$

Problem #5

```
import numpy as np

if __name__ == "__main__":
    '''
    This will create a 3x3 numpy array object like so:

    1 2 3
    4 5 6
    7 8 9

    '''
    a = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])


    '''
    This will get the third row of values
    [get list @ index 2, get all values in this list]
    so b = [4,5,6]
    '''
    b = a[2, :]



    '''
    This will flatten the array a to a 1d array with all of the values
    so c = [1,2,3,4,5,6,7,8,9]
    '''
    c = a.reshape(-1)


    '''
    this will create a 5x1 vector of random floating point numbers randomly sampled
from
    a normal distrobution
    '''
    f = np.random.randn(5, 1)


    '''
    f>0 will create a boolean array where every element is compared
    to 0 those that are greater will have true at that index those that are less will
    have false. A numpy array can be indexed by booleans where any index that
    is true in the boolean array will have a coresponding value appear in the
    resultant array. So g will contain any values in f that mee the condition
    f>0
    '''
    g = f[f > 0]


    '''
    zeros will create a vector of zeros with length 10 the addition will add .5 to
    all values in the vector so the result will be a vector containing 10 0.5 floats
    '''
    x = np.zeros(10) + 0.5
```

```
   '''
   this will create a vector of ones whose size will be the length of another vector x
so in
   this case 10. It will then perform scalar multiplication on the vector. The result
will
   be a vector of length 10 containing all 0.5 floats
   '''
   y = 0.5 * np.ones(len(x))


   '''
   This will perform vector addition between x and y the result will be a vector of
length 10
   containing all 1s.
   '''
   z = x + y


   '''
   this will create an array that spans the range 1 to 100 [exclusive]
   with a default step size of 1 so [1,2,3,..99].
   '''
   a = np.arange(1, 100)

   '''
   The slice notation is as follows list[<start>:<stop>:<step>]
   By default this will span the entire list if no args are given
   the step of minus 1 will step backwards through the list reversing it

   refecerenced:
   https://stackoverflow.com/questions/31633635/what-is-the-meaning-of-inta-1-in-
python#:~:text=The%20notation%20that%20is%20used,stop_index%3E%2C%20%5D
   '''
   b = a[::-1]


   '''
   given 1 argument this function will create a vector with range 0 to n-1 and
randomly permute
   [shuffle] all of the values in the generated array. If given an array it would
shuffle it. so
   in this case we create a vector [0,1,2,..9] and randomly permute it
   '''
   c = np.random.permutation(10)
```

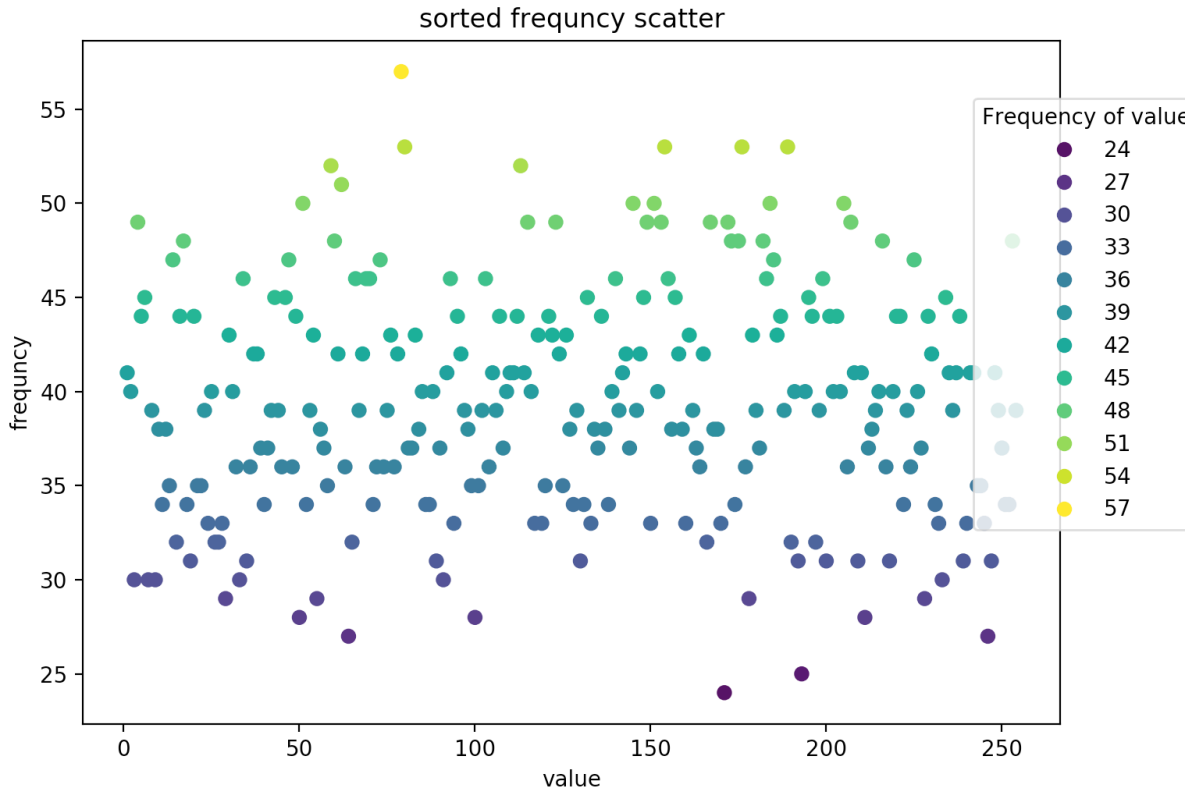
5B

```
   #1
   y = np.array([1, 2, 3, 4, 5, 6])
   z = y.reshape(3,2)

   #2
   x = np.max(z)
   r,c = np.where(z==x)
   r = r[0]
   c = c[0]

   #3
   v = np.array([1, 8, 8, 2, 1, 3, 9, 8])
```

```
    x = np.count_nonzero(v == 1)

    #4
    n = 4
    DiceRolls = np.random.randint(1,7,size = n)
```

5c

```
import numpy as np
import matplotlib.pylab as plt


def createFile(path,DataSource):
    np.savetxt(path, DataSource, fmt='%d')

def getFreq(list):
    list = list.reshape(-1).tolist()
    freqDict = {}
    for x in list:
        freqDict[x] = list.count(x)
    return freqDict

if __name__ == '__main__':

    #1
    path = 'inputP5A.npy'
    DataSource = np.random.randint(1, 255, (100, 100))
    #createFile(path,DataSource)
    A = np.loadtxt('inputP5A.npy', dtype=int)
    f = getFreq(A)
    valueFreqList = sorted(f.items(), key=lambda x: x[1], reverse=True)
    print("Ordered Intensity List")
    print(valueFreqList)
    #valueFreqList = sorted(f.items())
    x, y = zip(*valueFreqList)  # unpack a list of pairs into two tuples
    #plt.plot(y)

    fig, ax = plt.subplots()
    scatter = ax.scatter(x , y, c=y)
    ax.legend(*scatter.legend_elements(),title='Frequency of value',bbox_to_anchor=(.9,
.6),loc='center left')
    plt.title('sorted frequncy scatter')
    plt.xlabel('value')
    plt.ylabel('frequncy')
    plt.show()
    #fig1.savefig('Frequncy_VS_value_5_c_1.png')
```




```
[(79, 57), (176, 53), (189, 53), (154, 53), (80, 53), (59, 52), (113, 52), (62, 51),
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(207, 49), (153, 49), (149, 49), (123, 49), (172, 49), (216, 48), (60, 48), (173, 48),
(17, 48), (253, 48), (175, 48), (182, 48), (225, 47), (47, 47), (185, 47), (73, 47),
(14, 47), (140, 46), (103, 46), (183, 46), (66, 46), (93, 46), (155, 46), (199, 46),
(34, 46), (70, 46), (69, 46), (234, 45), (43, 45), (132, 45), (148, 45), (157, 45),
(6, 45), (46, 45), (195, 45), (196, 44), (203, 44), (136, 44), (220, 44), (95, 44),
(49, 44), (5, 44), (221, 44), (112, 44), (20, 44), (229, 44), (107, 44), (121, 44),
(16, 44), (201, 44), (238, 44), (187, 44), (186, 43), (118, 43), (161, 43), (30, 43),
(126, 43), (179, 43), (54, 43), (76, 43), (83, 43), (122, 43), (143, 42), (96, 42),
(230, 42), (78, 42), (165, 42), (37, 42), (38, 42), (124, 42), (68, 42), (147, 42),
(158, 42), (61, 42), (235, 41), (110, 41), (241, 41), (237, 41), (92, 41), (208, 41),
(105, 41), (1, 41), (242, 41), (248, 41), (210, 41), (142, 41), (114, 41), (111, 41),
(226, 40), (85, 40), (215, 40), (2, 40), (88, 40), (25, 40), (116, 40), (109, 40),
(139, 40), (204, 40), (191, 40), (202, 40), (152, 40), (219, 40), (194, 40), (31, 40),
(106, 39), (102, 39), (236, 39), (97, 39), (249, 39), (8, 39), (254, 39), (23, 39),
(223, 39), (214, 39), (42, 39), (198, 39), (75, 39), (141, 39), (188, 39), (44, 39),
(180, 39), (67, 39), (162, 39), (146, 39), (129, 39), (53, 39), (12, 38), (137, 38),
(98, 38), (156, 38), (213, 38), (134, 38), (168, 38), (84, 38), (56, 38), (159, 38),
(169, 38), (10, 38), (127, 38), (41, 37), (81, 37), (39, 37), (82, 37), (135, 37),
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(45, 36), (77, 36), (36, 36), (72, 36), (48, 36), (177, 36), (224, 36), (120, 35),
(22, 35), (21, 35), (58, 35), (125, 35), (99, 35), (244, 35), (101, 35), (13, 35),
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(40, 34), (71, 34), (86, 34), (18, 34), (231, 34), (222, 34), (128, 34), (11, 34),
(94, 33), (24, 33), (240, 33), (119, 33), (160, 33), (133, 33), (28, 33), (232, 33),
(170, 33), (150, 33), (117, 33), (245, 33), (190, 32), (27, 32), (26, 32), (65, 32),
(166, 32), (197, 32), (15, 32), (239, 31), (19, 31), (200, 31), (130, 31), (89, 31),
```
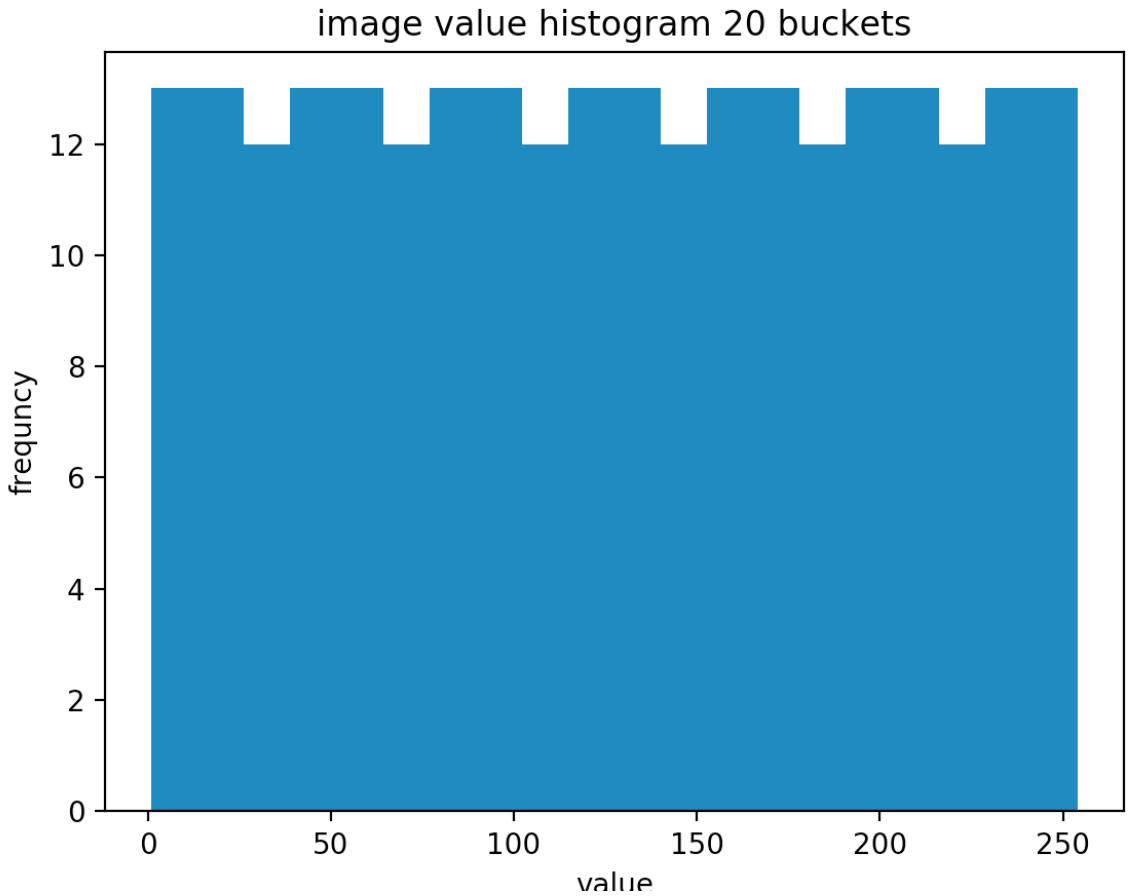
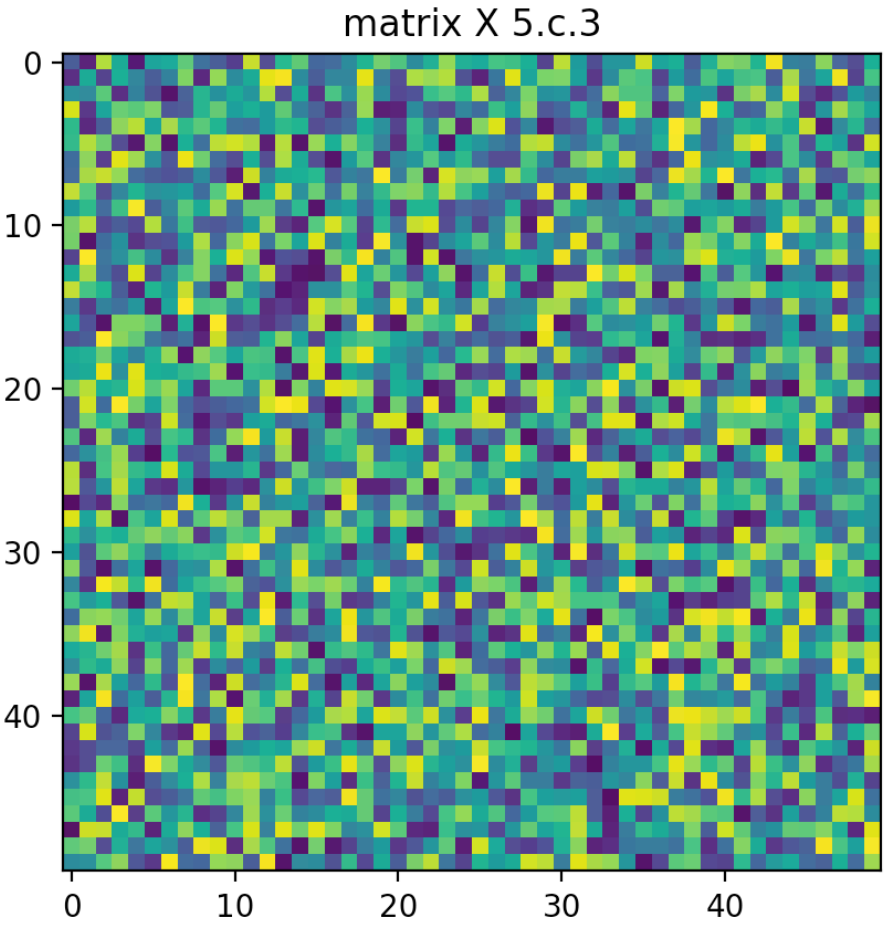

```
(192, 31), (247, 31), (35, 31), (209, 31), (218, 31), (233, 30), (7, 30), (33, 30),
(3, 30), (91, 30), (9, 30), (178, 29), (55, 29), (29, 29), (228, 29), (100, 28), (211,
28), (50, 28), (64, 27), (246, 27), (193, 25), (171, 24)]
```

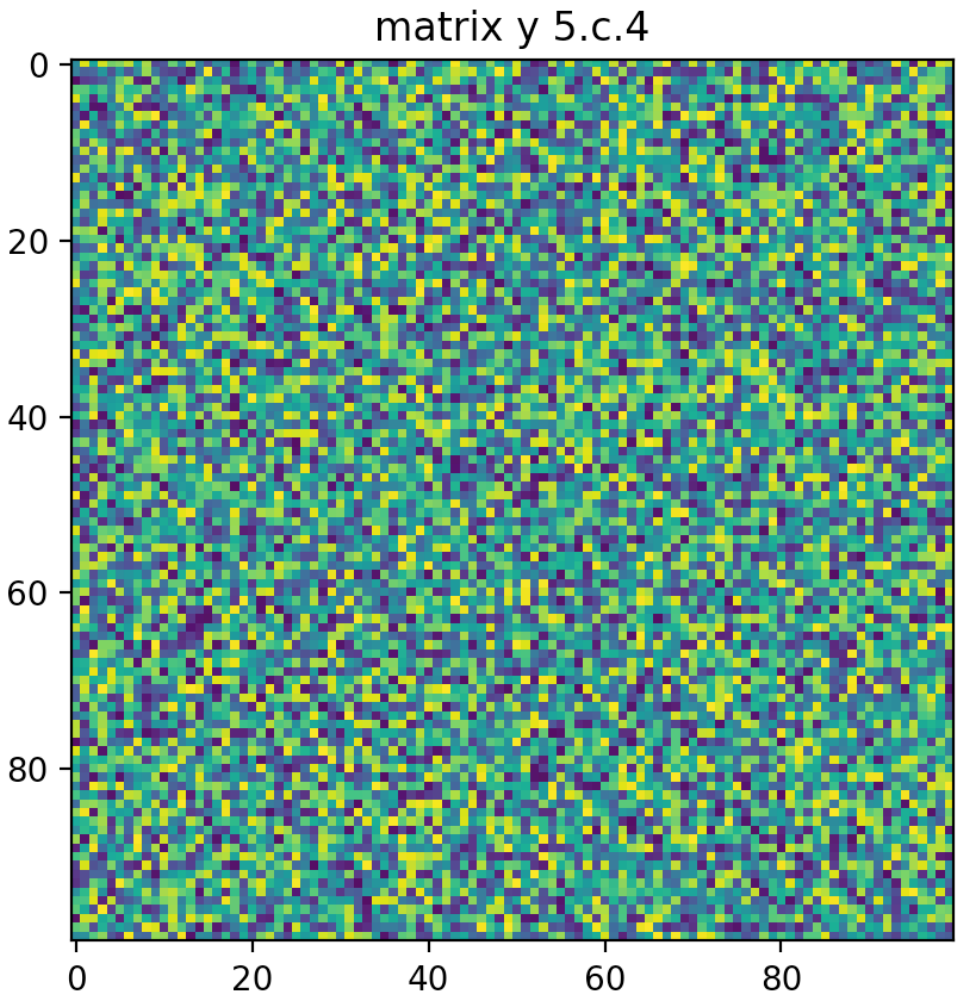
```
#2
plt.hist(x, density=False, bins=20)
plt.title('image value histogram 20 buckets')
plt.xlabel('value')
plt.ylabel('frequncy')
plt.show()
#fig2.savefig('Value_Histogram_5_c_2.png')
```



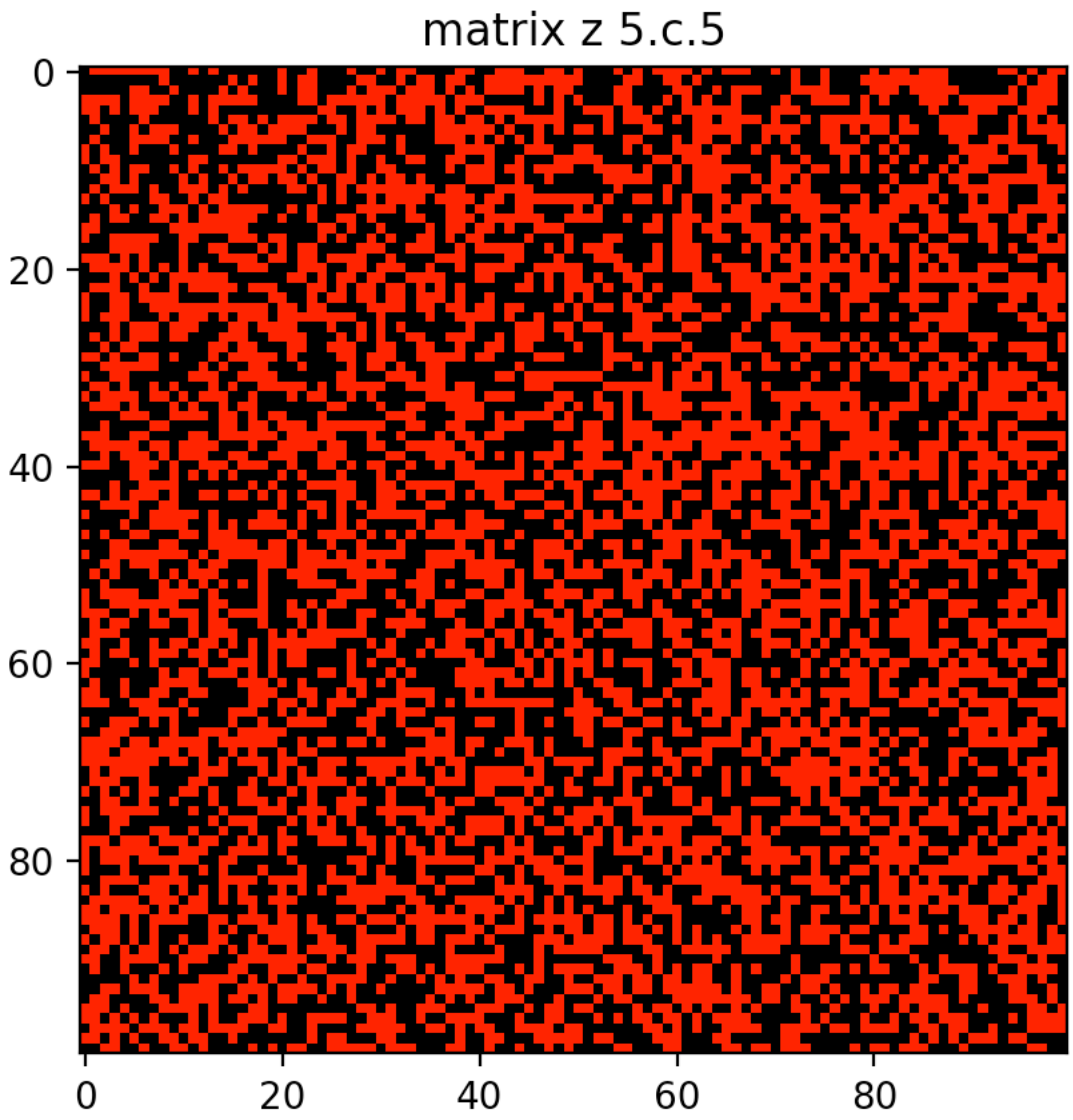

```
#3
x = [M for SubA in np.split(A,2, axis = 0) for M in np.split(SubA,2, axis = 1)][2]
plt.matplotlib.pyplot.imshow(x,interpolation='none')
plt.title('matrix X 5.c.3')
plt.show()
#fig3.savefig('Left_Quad_5_c_3.png')
path = 'outputP5X.npy'
createFile(path,x)
```




```
#4
Y = A - np.mean(A)
plt.matplotlib.pyplot.imshow(Y, interpolation='none')
plt.title('matrix y 5.c.4')
plt.show()
#fig4.savefig('Average_Diffed_5_c_4.png')
path = 'outputP5Y.npy'
createFile(path,Y)
```




```
#5
Z = np.ones((100,100))*255
Z[A <= np.mean(A) ] = 0
Z = [[red,0,0] for row in Z for red in row]
Z = np.array(Z, dtype=np.uint8).reshape((100, 100, 3))
plt.matplotlib.pyplot.imshow(Z, interpolation='none')
plt.title('matrix z 5.c.5')
plt.show()
plt.matplotlib.pyplot.imshow(Z, interpolation='none')
plt.title('matrix z 5.c.5')
plt.savefig('outputP5Z.png')
```




```
   #####references

   '''
   https://www.geeksforgeeks.org/counting-the-frequencies-in-a-list-using-dictionary-
in-python/
   https://stackoverflow.com/questions/37266341/plotting-a-python-dict-in-order-of-
key-values/37266356
   https://stackoverflow.com/questions/12811981/slicing-python-matrix-into-quadrants
   '''
```

Problem #6

```
import cv2
import math
import numpy as np


class Kernal:

   def __init__(self,N,sigma):
      self.N = N
      self.sigma = sigma
      self.frontBit = 1 / (sigma ** 2 * 2 * math.pi)
      self.k = np.zeros((N, N))
      self.idxMin = int(N / 2)
      for i in range(N):
         for j in range(N):
            x, y = self.getXYfromIDX(i, j)
            self.k[i, j] = self.frontBit * math.exp(-(x ** 2 + y ** 2) / (2 * sigma **
2))



   def getXYfromIDX(self,i,j):
      x = i-self.idxMin
      y = j-self.idxMin
      return x, y


class Image:

   paddingOffset = None

   def __init__(self,fpath):
      self.image = cv2.imread(fpath, 0) #np.array([[1,2,3],[4,5,6],[7,8,9]])#
      self.height = len(self.image)
      self.width = len(self.image[0])

   def setPadding(self,width):

      #from numpy docs @
https://numpy.org/doc/stable/reference/generated/numpy.pad.html
      def pad_with(vector, pad_width, iaxis, kwargs):
         pad_value = kwargs.get('padder', 10)
         vector[:pad_width[0]] = pad_value
         vector[-pad_width[1]:] = pad_value

      padded = np.pad(self.image, width, pad_with, padder=0)
      self.paddingOffset = width
      self.padded = padded



   def convolve(self,k):
      #thankfully kernal is symetric so no flipy bois
      for r in range(self.height):
         print(r)
         for c in range(self.width):
            cellVal= 0
```

```
            for y in range (k.N):
                for x in range(k.N):
                    cellVal += self.padded[r+x,c+y] * k.k[x,y]
            self.image[r,c] = cellVal
        # print("plz")
        # print(self.image)


if __name__ == '__main__':
    fpath = 'inputP6.jpg'

    I1 = Image(fpath)
    kern = Kernal(5, 1.414)
    I1.setPadding(kern.idxMin)
    cv2.imshow("preconvolve", I1.image)
    I1.convolve(kern)
    cv2.imshow("postconvolve3", I1.image)


    cv2.waitKey(0)
```