Computer Assignment 3

Problem 1

In [10]:
```
import numpy as np
import cv2
import matplotlib.pyplot as plt
import math
import pywt
from collections import deque
from copy import deepcopy
```

In [11]:
```
pyramidTypes = ["Gaussian", "Laplacian"]
```

In [12]:
```
#Function to compute Gaussian Pyramid of given image
def gaussianPyramid(image, j_level):
  gaussian_pyramid_images = []
  for i in range(j_level):
    if i == 0:
      gaussian_pyramid_images.append(image)

    elif image.shape[0] > 1 and image.shape[1] > 1:
      image = cv2.resize(image, (image.shape[1]//2, image.shape[0]//2), interpolation=cv2.INTER_LINEAR)
      gaussian_pyramid_images.append(image)

  return gaussian_pyramid_images
```

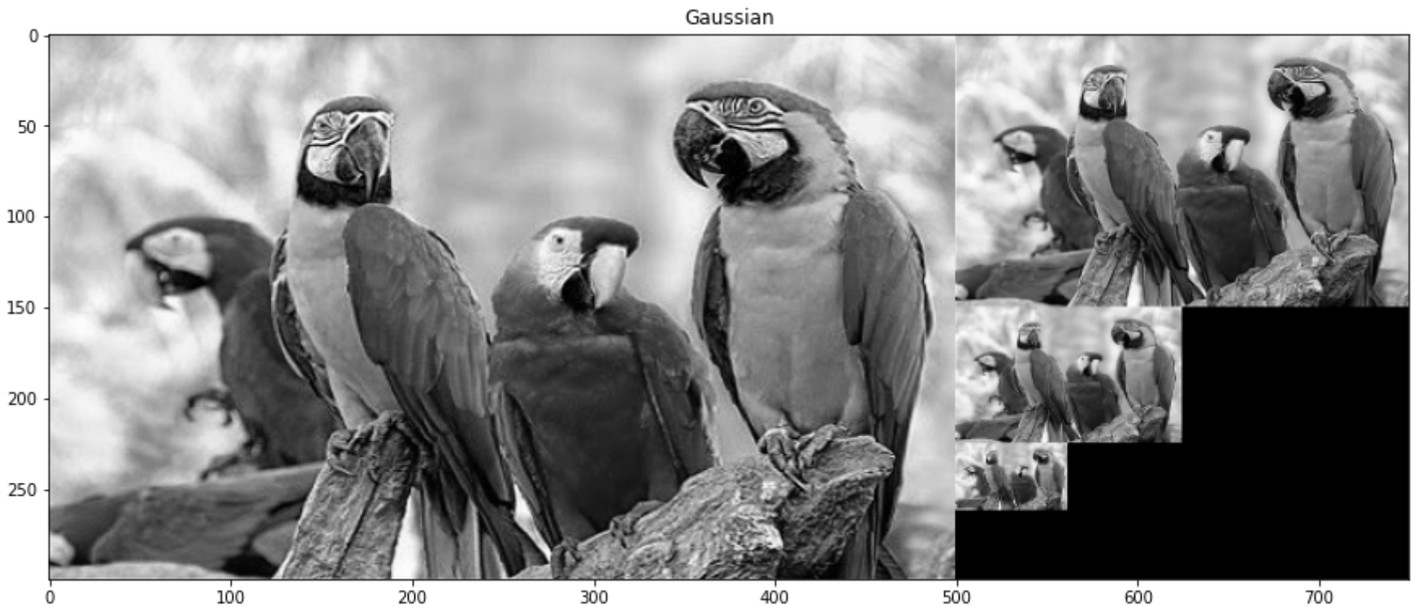
In [13]:
```
#Function to compute Laplacian Pyramid of given image
def laplacianPyramid(image, j_level):
  laplacian_pyramid_images = []
  for i in range(j_level):
    if i == j_level - 1:
      laplacian_pyramid_images.append(image)

    elif image.shape[0] > 1 and image.shape[1] > 1:
      image_d = cv2.resize(image, (image.shape[1]//2, image.shape[0]//2), interpolation=cv2.INTER_LINEAR)
      image_u = cv2.resize(image_d, (image.shape[1], image.shape[0]), interpolation=cv2.INTER_CUBIC)
      l_image = image - image_u
      laplacian_pyramid_images.append(l_image)
      image = image_d

  return laplacian_pyramid_images
```

In [14]:
```
def getPyramid(image, pyramid_type, level):
  if pyramid_type == pyramidTypes[0]:
    pyramid = gaussianPyramid(image, level)

  elif pyramid_type == pyramidTypes[1]:
    pyramid = laplacianPyramid(image, level)

  return pyramid
```

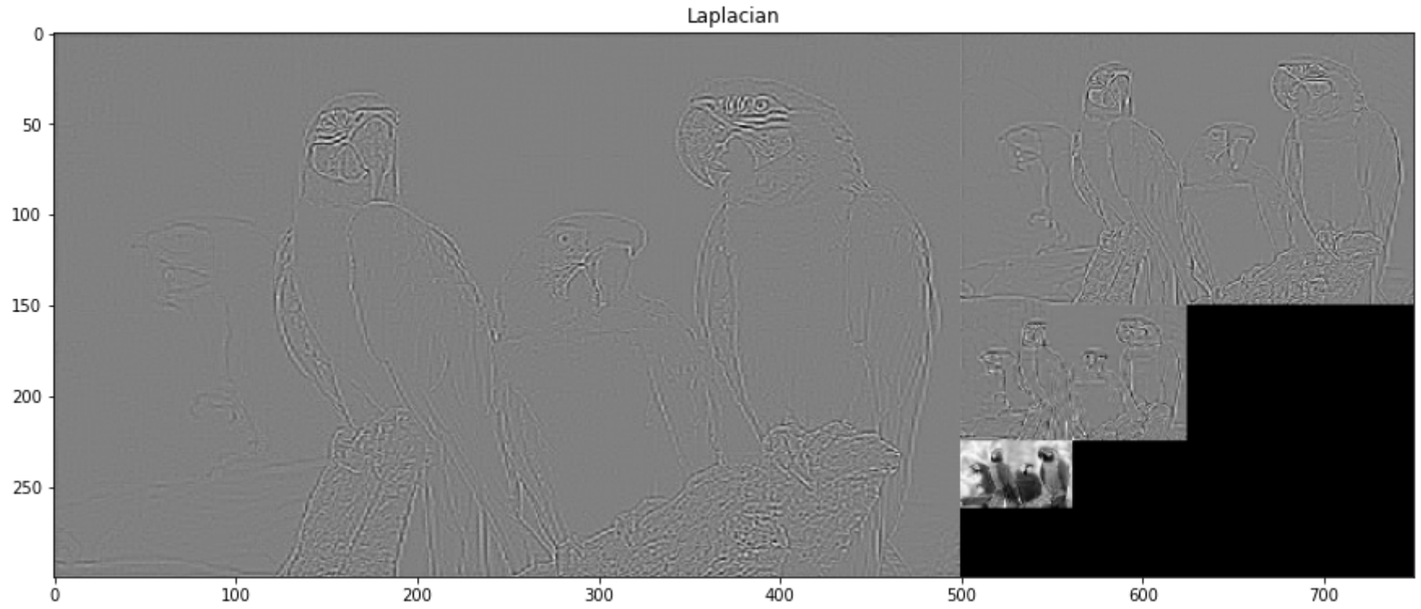
In [15]:
```
def displayPyramid(image, pyramid_type, level):
  rows, cols = image.shape
  pyramid = getPyramid(image, pyramid_type, level)

  #Normalize the values in case of laplacian pyramid so that it can be displayed properly
```

```
  if pyramid_type == pyramidTypes[1]:
    for i in range(len(pyramid)):
      pyramid[i] = np.round((pyramid[i]-np.min(pyramid[i]))*255/(np.max(pyramid[i])-np.min(pyramid[i])))

  #To Display image in composite manner,
  composite_image = np.zeros((rows, cols+cols//2), dtype=np.float64)
  composite_image[:rows, :cols] = pyramid[0]

  i_row = 0
  for p in pyramid[1:]:
      n_rows, n_cols = p.shape
      composite_image[i_row:i_row + n_rows, cols:cols + n_cols] = p
      i_row += n_rows

  plt.figure(figsize = (15,7))
  plt.imshow(composite_image, cmap='gray')
  plt.title(pyramid_type)
```

In [16]:
```
#Display Gaussian Pyramid upto J=3
img = cv2.imread("bird2.jpg", cv2.IMREAD_GRAYSCALE).astype(float)
displayPyramid(img, pyramidTypes[0], 4)
```



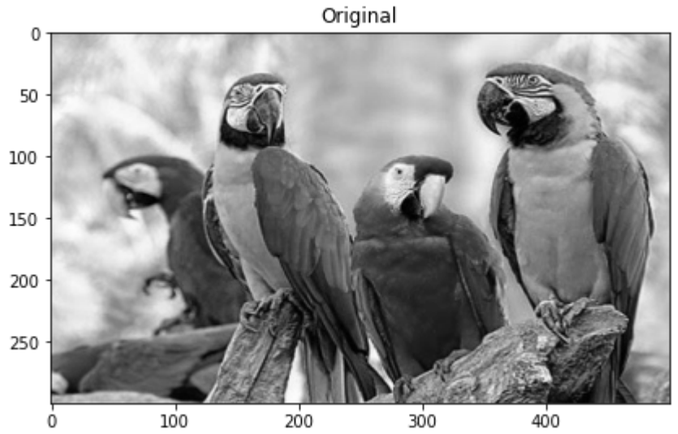
In [17]:
```
#Display Laplacian Pyramid upto J=3
img = cv2.imread("bird2.jpg", cv2.IMREAD_GRAYSCALE).astype(float)
displayPyramid(img, pyramidTypes[1], 4)
```

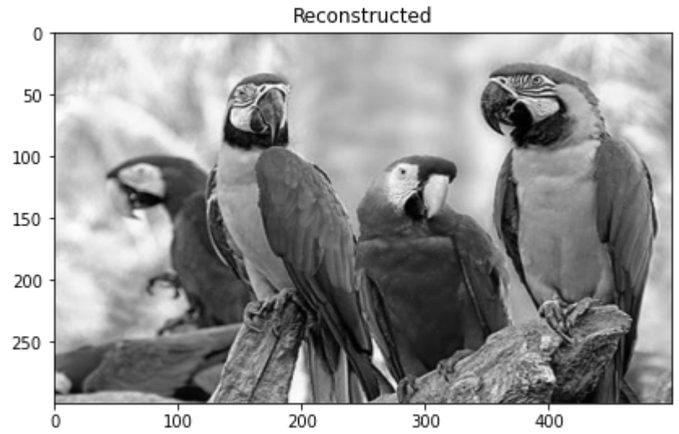


In [18]:
```
def reconstructLaplacian(l_pyramid):
  r_image = l_pyramid[0]
  for i in range(len(l_pyramid)-1):
    rev_i = len(l_pyramid) - i - 2
    if i == 0:
      r_image = l_pyramid[rev_i] + cv2.resize(l_pyramid[rev_i+1], (l_pyramid[rev_i].shape[1], l_pyramid[rev_i].shape[0]), interpolation = cv2.INTER_CUBIC)
    else:
      r_image = l_pyramid[rev_i] + cv2.resize(r_image, (l_pyramid[rev_i].shape[1], l_pyramid[rev_i].shape[0]), interpolation = cv2.INTER_CUBIC)

  return r_image
```

In [19]:
```
#Reconstruct Image from Laplacian Pyramid
img = cv2.imread("bird2.jpg", cv2.IMREAD_GRAYSCALE).astype(float)
l_pyramid = laplacianPyramid(img, 4)
reconstructed_image = reconstructLaplacian(l_pyramid)
plt.figure(figsize = (15,7))

plt.subplot(1, 2, 1)
plt.imshow(img, cmap='gray')
plt.title("Original")

plt.subplot(1, 2, 2)
plt.imshow(reconstructed_image, cmap='gray')
plt.title("Reconstructed")
```

Out[19]:
```
Text(0.5, 1.0, 'Reconstructed')
```





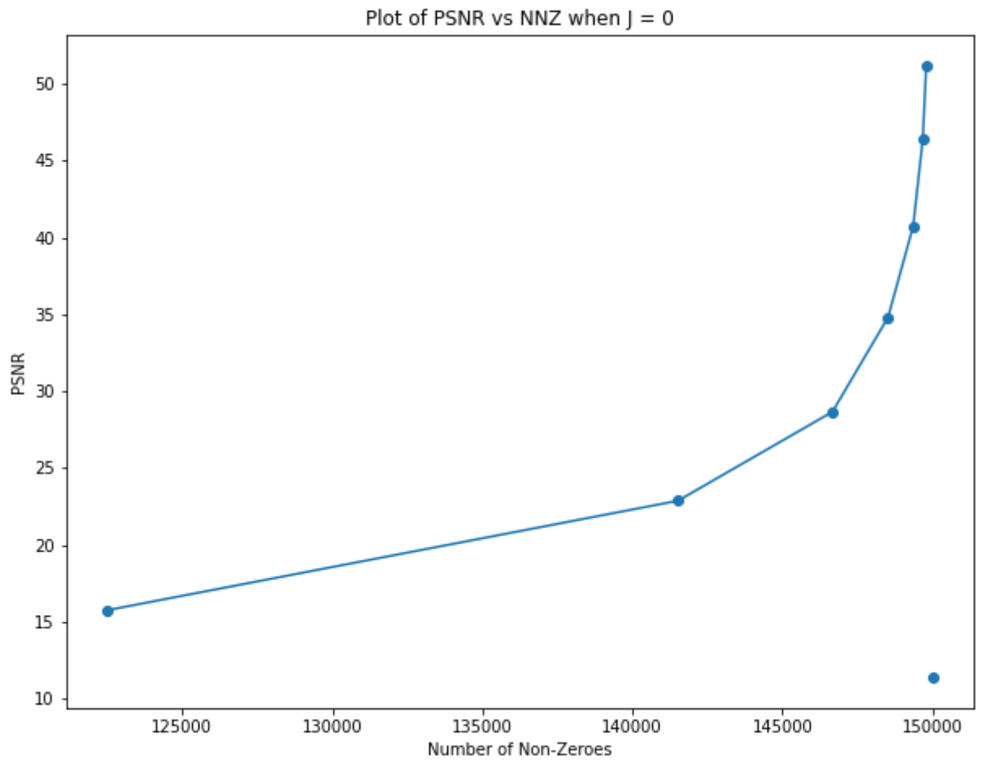
In [20]:
```python
#Q: Step Size,
def quantizePyramid(pyramid, Q):
  quantized_pyramid = deepcopy(pyramid)

  mean = []
  for i in range(len(pyramid)):
    if i < len(pyramid) - 1:
      mean.append(0)
    elif i == len(pyramid) - 1:
      mean.append(128)

  for i in range(len(pyramid)):
    quantized_pyramid[i] = Q*np.floor((pyramid[i]-mean[i])/Q + 0.5) + mean[i]

  return quantized_pyramid
```

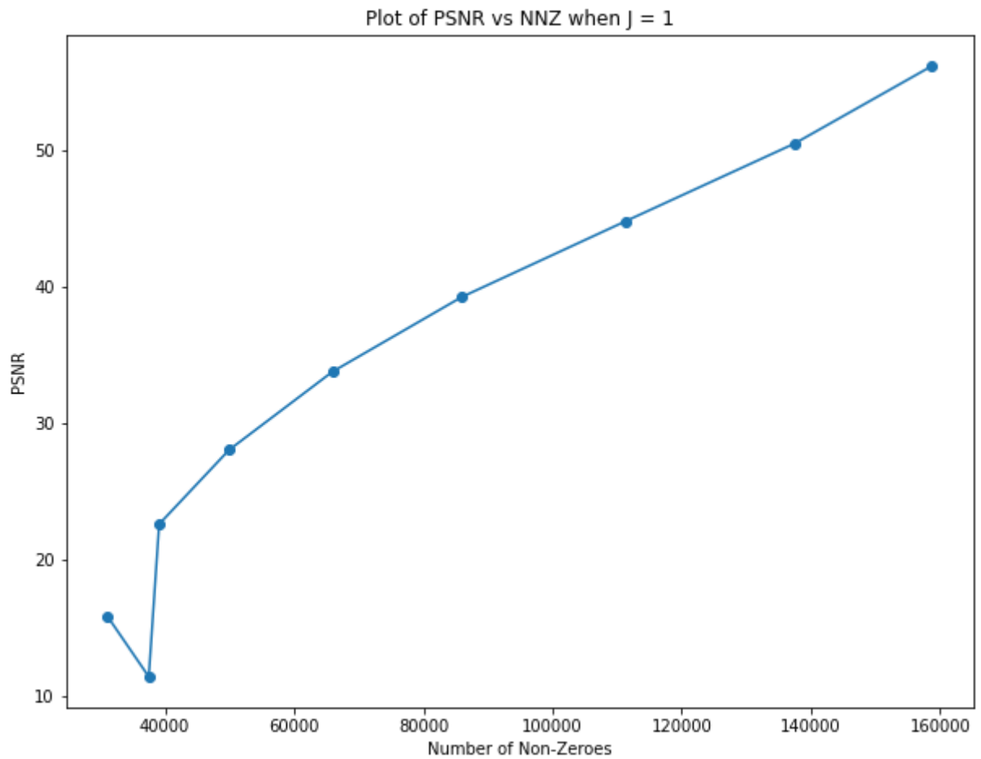
In [21]:
```python
def numOfNonZeroes(pyramid):
  val = 0
  for i in range(len(pyramid)):
    val += np.count_nonzero(pyramid[i])

  return val
```

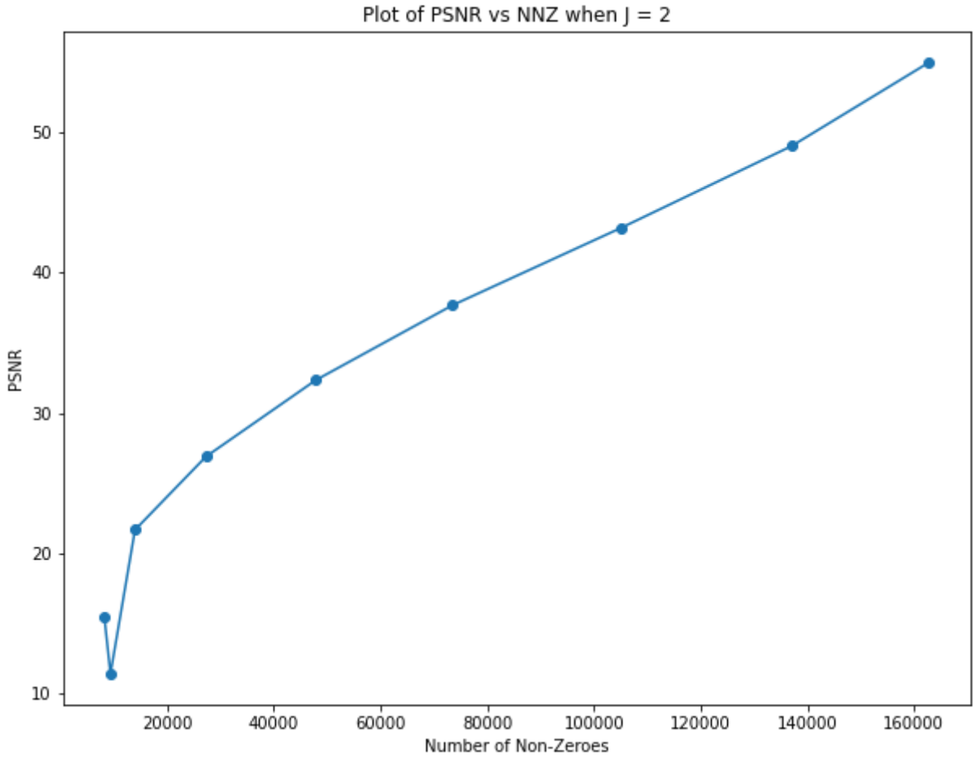
In [34]:
```python
#Main Function 1 to plot PSNR vs NNZ graph
img = cv2.imread("bird2.jpg", cv2.IMREAD_GRAYSCALE).astype(float)

for j_level in range(1, 5):
  pyramid = laplacianPyramid(img, j_level)
  nnz = []
  psnr = []
  for i in range(9):
    Q = 2**i
    quantized_pyramid = quantizePyramid(pyramid, Q)
    reconstructed_image = reconstructLaplacian(quantized_pyramid)
    nnz.append(numOfNonZeroes(quantized_pyramid))
    psnr.append(10*np.log10((255**2)/np.mean((reconstructed_image - img)**2)))

  psnr_nnz = zip(nnz, psnr)
  sorted_psnr_nnz = sorted(psnr_nnz)
  nnz, psnr = zip(*sorted_psnr_nnz)

  plt.figure(figsize = (10,35))
  plt.subplot(4, 1, j_level)
  plt.plot(nnz, psnr, marker='o')
  plt.xlabel("Number of Non-Zeroes")
```

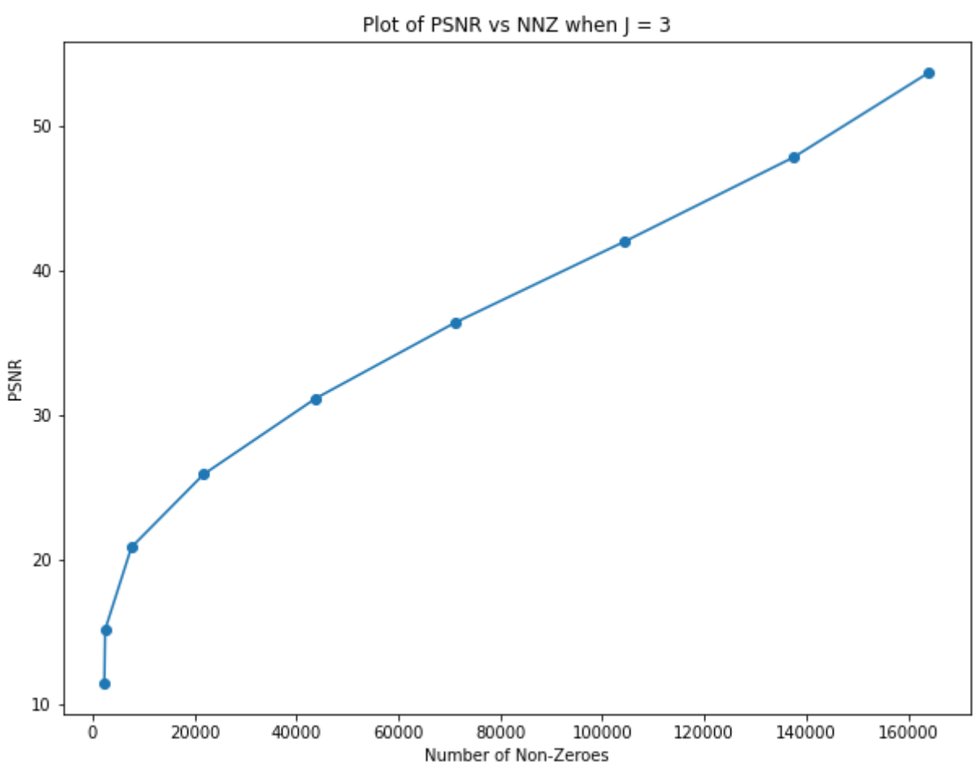
```
  plt.ylabel("PSNR")
  plt.title("Plot of PSNR vs NNZ when J = " + str(j_level-1))
```

```
<ipython-input-34-c66ad8018e8d>:13: RuntimeWarning: divide by zero encountered in double_scalars
  psnr.append(10*np.log10((255**2)/np.mean((reconstructed_image - img)**2)))
```






Plot of PSNR vs NNZ when J = 2
PSNR
Number of Non-Zeroes
10
20
30
40
50
20000
40000
60000
80000
100000
120000
140000
160000


Plot of PSNR vs NNZ when J = 3
PSNR
Number of Non-Zeroes
10
20
30
40
50
0
20000
40000
60000
80000
100000
120000
140000
160000

Answer 1. d

We can observe that as depth of pyramid increases, with less number of non-zero values, high PSNR value can be acheived. Or we can say that representation efficiency increases with increasing depth.

Yes this was expected as more number of levels means more details can be captured and hence more efficient representation.

Answer 1. e

Higher PSNR means better quality of image (very less noise). Hence, if there is large increase in PSNR value, image quality be different. Hence, we observe that for J=3, when quantization value was low i.e. 2 or 4, there was very less change in PSNR value and hence at that time it was un-noticeable.

Problem 2

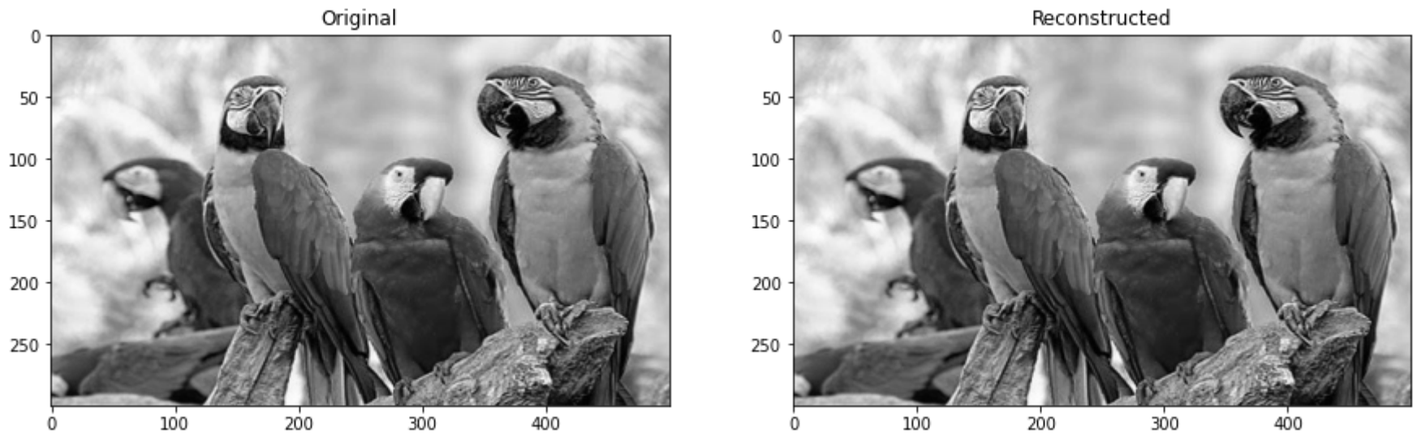
In [1]:
```
def wavelet_transform(image, level):
  haar_wavelet = 'db1'
  wavelets = deque()
  wavelets.append(image)

  for i in range(level):
    approx, (horiz, vert, diag) = pywt.dwt2(wavelets.popleft(), haar_wavelet, mode='symmetric')
    wavelets.appendleft((horiz, vert, diag))
    wavelets.appendleft(approx)

  return wavelets
```

In [2]:
```
def reconstruct_wavelet(wavelets):
  haar_wavelet = 'db1'
  length = len(wavelets)
  levels = length-1
  wavelets = deepcopy(wavelets)

  for i in range(levels):
    temp1 = wavelets.popleft()
    temp2 = wavelets.popleft()

    #To make dimensions of image recontructed at certain level and co-efficients of next level
    #Here, we ignore extra length created during image reconstruction by pywt.idwt2()
    if temp1.shape[0] != temp2[0].shape[0]:
            temp1 = temp1[0:-1,:]
    if temp1.shape[1] != temp2[0].shape[1]:
            temp1 = temp1[:,0:-1]

    temp_wavelet = (temp1, temp2)
    temp_image = pywt.idwt2(temp_wavelet, haar_wavelet, mode='symmetric')
    wavelets.appendleft(temp_image)

  return wavelets.popleft()
```

In [5]:
```
#Display Original and Reconstructed image to verify wavelets construction and reconstruction is working fine
original_image = cv2.imread("bird2.jpg", cv2.IMREAD_GRAYSCALE).astype(float)

wavelets = wavelet_transform(original_image, 3)
recontructed_image = reconstruct_wavelet(wavelets)

plt.figure(figsize = (15,7))

plt.subplot(1, 2, 1)
plt.imshow(original_image, cmap='gray')
plt.title("Original")
```

```
plt.subplot(1, 2, 2)
plt.imshow(recontructed_image, cmap='gray')
plt.title("Reconstructed")
```

Out[5]:
```
Text(0.5, 1.0, 'Reconstructed')
```

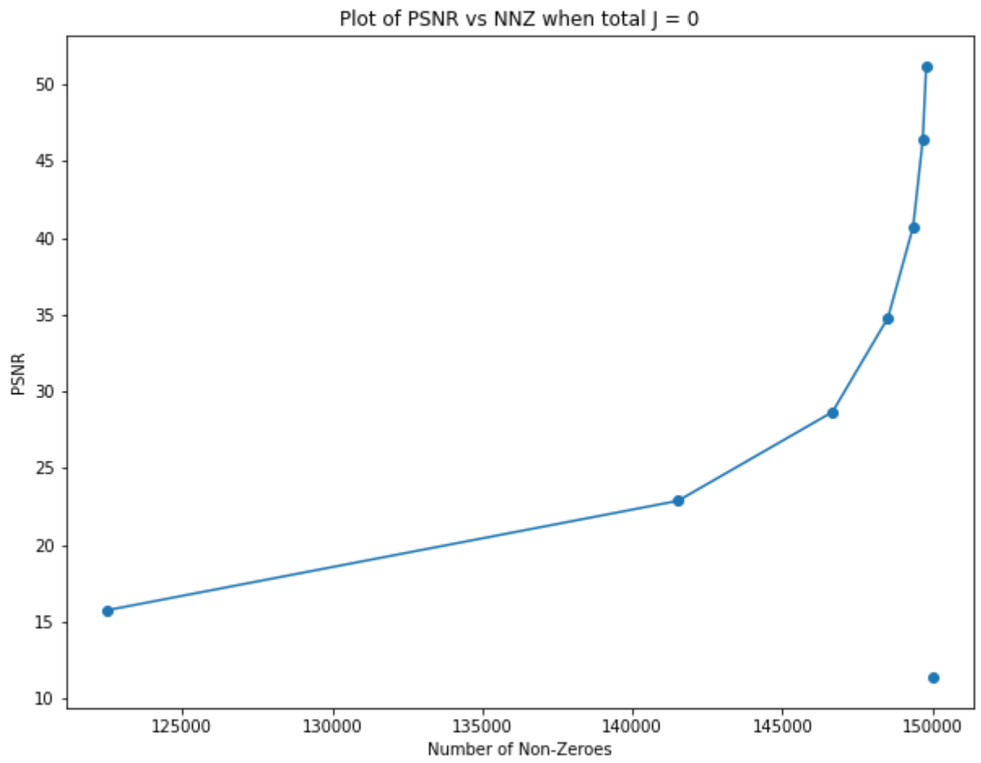


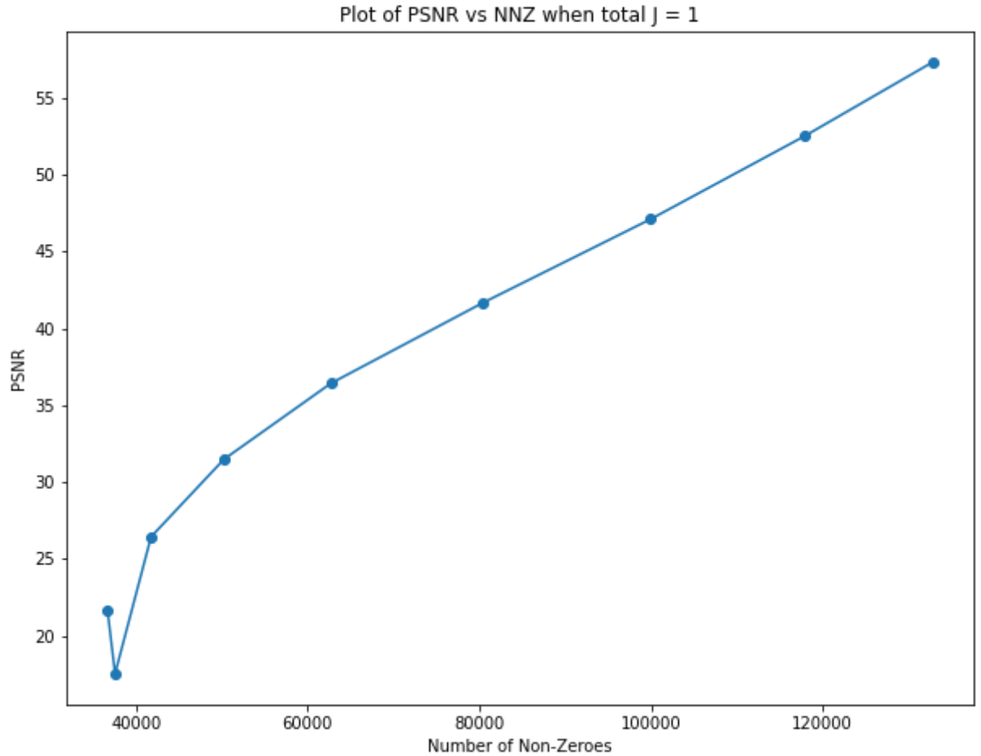
In [6]:
```
#Q: Step Size,
def quantizeWavelets(wavelets, Q):
  quantized_wavelets = deepcopy(wavelets)

  for i in range(len(quantized_wavelets)):
    if i != 0:
      quantized_wavelets[i] = list(quantized_wavelets[i])

  mean = []
  for i in range(len(wavelets)):
    if i == 0:
      mean.append(128)
    else:
      mean.append(0)

  for i in range(len(wavelets)):
    if i == 0:
      quantized_wavelets[i] = Q*np.floor((wavelets[i]-mean[i])/Q + 0.5) + mean[i]
    else:
      for j in range(3):
        quantized_wavelets[i][j] = Q*np.floor((wavelets[i][j]-mean[i])/Q + 0.5) + mean[i]

  for i in range(len(quantized_wavelets)):
    if i != 0:
      quantized_wavelets[i] = tuple(quantized_wavelets[i])

  return quantized_wavelets
```

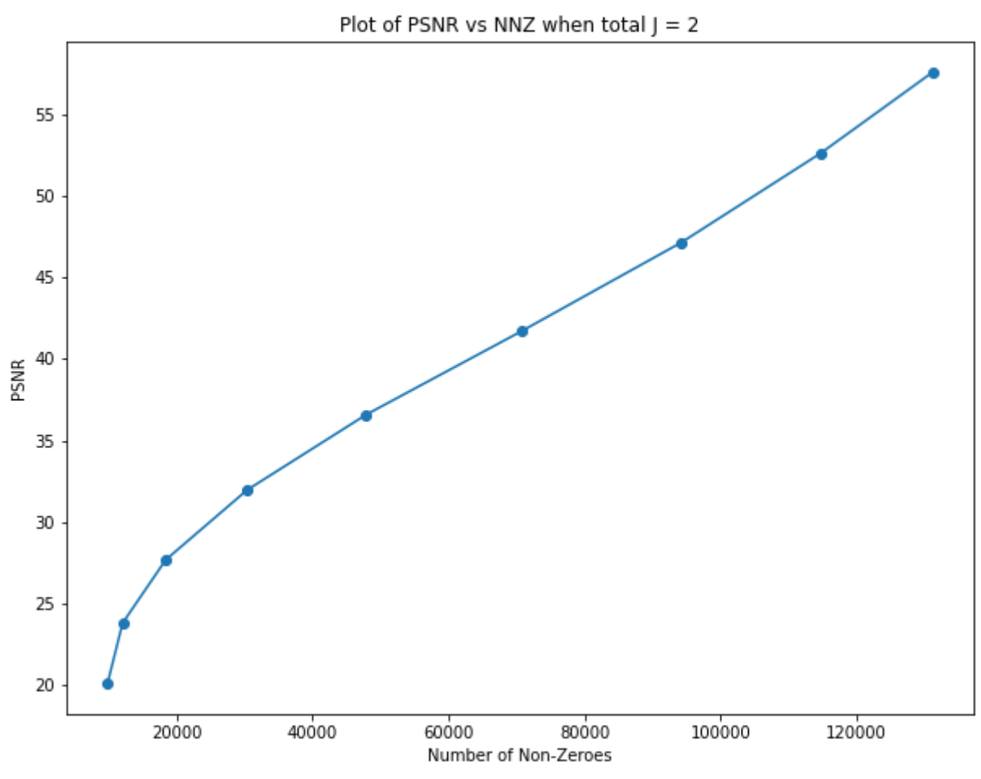
In [7]:
```
def numOfNonZeroesWavelets(wavelets):
  val = 0
  for i in range(len(wavelets)):
    if i == 0:
      val += np.count_nonzero(wavelets[i])
    else:
      for j in range(3):
        val += np.count_nonzero(wavelets[i][j])
  return val
```

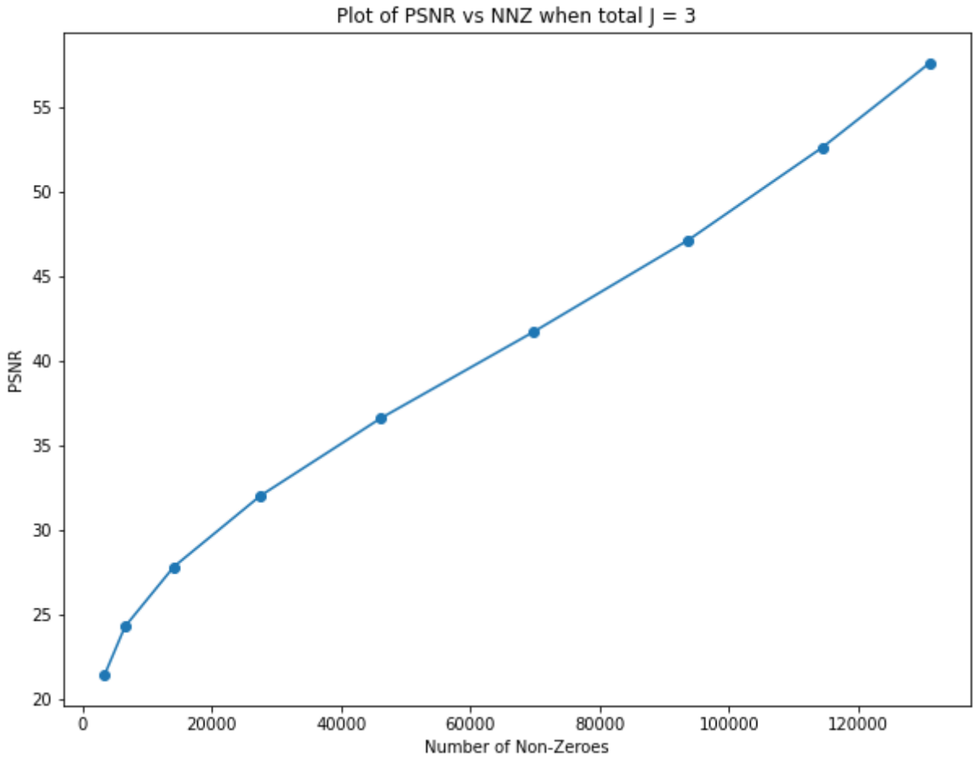
In [33]:
```
#Main Function 2
img = cv2.imread("bird2.jpg", cv2.IMREAD_GRAYSCALE).astype(float)

for j_level in range(0, 4):
  wavelets = wavelet_transform(img, j_level)
  nnz = []
  psnr = []
  for i in range(9):
    Q = 2**i
    quantized_wavelets = quantizeWavelets(wavelets, Q)
    reconstructed_image = reconstruct_wavelet(quantized_wavelets)
    nnz.append(numOfNonZeroesWavelets(quantized_wavelets))
    psnr.append(10*math.log10((255**2)/np.mean((reconstructed_image - img)**2)))

  psnr_nnz = zip(nnz, psnr)
  sorted_psnr_nnz = sorted(psnr_nnz)
  nnz, psnr = zip(*sorted_psnr_nnz)

  plt.figure(figsize = (10,35))
  plt.subplot(4, 1, j_level+1)
  plt.plot(nnz, psnr, marker='o')
  plt.xlabel("Number of Non-Zeroes")
  plt.ylabel("PSNR")
  plt.title("Plot of PSNR vs NNZ when total J = " + str(j_level))
```

```
<ipython-input-33-bf3dbedc0bed>:13: RuntimeWarning: divide by zero encountered in double_scalars
  psnr.append(10*math.log10((255**2)/np.mean((reconstructed_image - img)**2)))
```




Plot of PSNR vs NNZ when total J = 1
PSNR
Number of Non-Zeroes
20
25
30
35
40
45
50
55
40000
60000
80000
100000
120000


Plot of PSNR vs NNZ when total J = 2
PSNR
Number of Non-Zeroes
20
25
30
35
40
45
50
55
20000
40000
60000
80000
100000
120000



Answer 2. c

If we compare plot of PSNR vs NNZ of laplacian pyramid and Wavelets, we can see that in case of wavelets, less number of non-zero values are required to acheive higher PSNR which means wavelets increase representation efficiency.