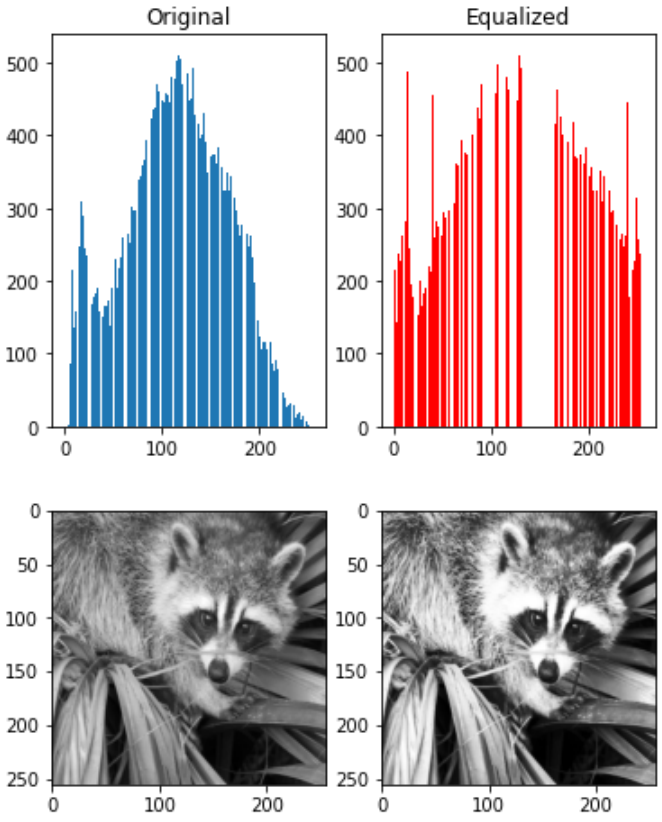
In [70]:
```
# Samantha Hong sh974
# ECE 4250 Assignment 2
import numpy as np
import scipy
from scipy import ndimage
from scipy import signal
import matplotlib
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
from PIL import Image
```

1. Histogram Equalization

Basic Histogram Equalization Algorithm

In [71]:
```
def make_hist(img):
    hist = np.zeros(256, dtype=int)
    for i in range(img.size):
        hist[img[i]] += 1
    return hist

def cumulative_sum(hist):
    cumsum = np.zeros(256, dtype=int)
    cumsum[0] = hist[0]
    for i in range(1, hist.size):
        cumsum[i] = cumsum[i-1] + hist[i]
    return cumsum

def map_values(img, cumsum):
    mapping = np.zeros(256, dtype=int)
    for i in range(256):
        mapping[i] = max(0, round((cumsum[i])/256-1))

    new_image = np.zeros(img.size, dtype=int)
    for i in range(img.size):
        new_image[i] = mapping[img[i]]
    return new_image
```

In [72]:
```
file = "X.png"
out_file = "X_histeq.png"

# Load image, store width and height into constants
img = Image.open(file)
orig = img
w, h = img.size

img = np.array(img).flatten()
histogram = make_hist(img)
cumsum = cumulative_sum(histogram)
img_histeq = map_values(img, cumsum)

output_image = Image.fromarray(np.uint8(img_histeq.reshape((w, h))))
output_image.save(out_file)

x_axis = np.arange(256)
fig = plt.figure()
fig.add_subplot(1, 2, 1)
plt.bar(x_axis, histogram)
plt.title('Original')
fig.add_subplot(1, 2, 2)
plt.bar(x_axis, make_hist(img_histeq), color="red")
plt.title('Equalized')
plt.show()

fig = plt.figure()
fig.add_subplot(1, 2, 1)
plt.imshow(orig, cmap='gray')
fig.add_subplot(1, 2, 2)
plt.imshow(output_image, cmap='gray')
plt.show()
```

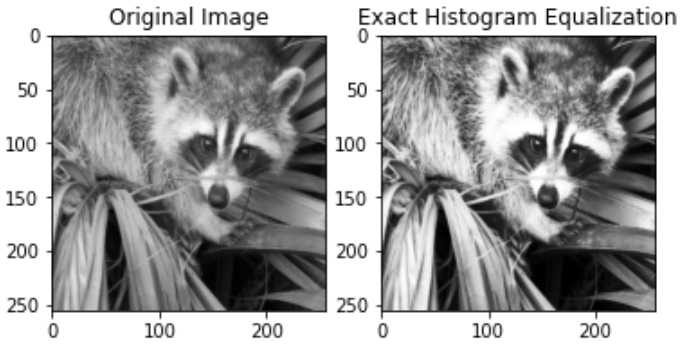


Exact Histogram Equalization Algorithm

In [73]:
```
# filter masks
m1 = 1./5 * np.array([[0, 1, 0],
                      [1, 1, 1],
                      [0, 1, 0]])

m2 = 1./9 * np.array([[1, 1, 1],
                      [1, 1, 1],
                      [1, 1, 1]])

m3 = 1./13 * np.array([[0, 0, 1, 0, 0],
                       [0, 1, 1, 1, 0],
                       [1, 1, 1, 1, 1],
                       [0, 1, 1, 1, 0],
                       [0, 0, 1, 0, 0]])

m4 = 1./21 * np.array([[0, 1, 1, 1, 0],
                       [1, 1, 1, 1, 1],
                       [1, 1, 1, 1, 1],
                       [1, 1, 1, 1, 1],
                       [0, 1, 1, 1, 0]])

m5 = 1./25 * np.array([[1, 1, 1, 1, 1],
                       [1, 1, 1, 1, 1],
                       [1, 1, 1, 1, 1],
                       [1, 1, 1, 1, 1],
                       [1, 1, 1, 1, 1]])
```

In [74]:
```
def exact_hist(img):
    img = np.asarray(img.convert('L'))
    flattened_img = img.flatten()

    image = np.array(img).flatten()
    masks = [m1, m2, m3, m4, m5]

    # convolve all masks and img
    conv_masks = np.array([signal.convolve2d(img, mask, 'same') for mask in mas
ks])

    # flatten and then lexicographically sort
    conv_masks = [mask.flatten() for mask in conv_masks]
    sorted_pixels = np.lexsort((conv_masks[0], conv_masks[1], conv_masks[2], co
nv_masks[3], conv_masks[4], image))

    # split ordered pixels into 256 different groups
    groups = np.split(sorted_pixels, 256)

    # assign intensity value j to pixels in group j
    for i in range(len(groups)):
        group = groups[i]
        for j in range(len(group)):
            flattened_img[group[j]] = i

    return flattened_img.reshape((256, 256))
```

In [75]:
```
img = Image.open(file)
fig = plt.figure()
fig.add_subplot(1, 2, 1)
plt.imshow(img, cmap='gray')
plt.title('Original Image')
fig.add_subplot(1, 2, 2)
plt.imshow(exact_hist(img), cmap='gray')
plt.title('Exact Histogram Equalization')
plt.show()
```

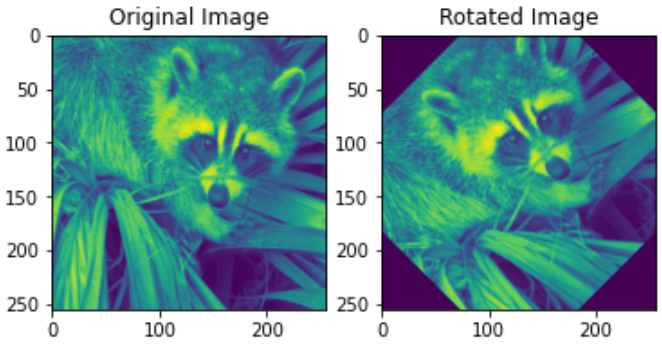


2. Spatial Transformations

Rotate2D

In [76]:
```
def Rotate2D(img, angle):
    width, height = img.shape
    theta = np.radians(-1*angle)
    cos, sin = np.cos(theta), np.sin(theta)
    rotated_img = np.zeros((width, height), dtype=int)

    to_center = np.array([[1, 0, width/2], [0, 1, height/2], [0, 0, 1]])
    from_center = np.array([[1, 0, -width/2], [0, 1, -height/2], [0, 0, 1]])
    matrix = np.array([[cos, -sin, 0], [sin, cos, 0], [0, 0, 1]])
    rotation_matrix = np.dot(np.dot(to_center, matrix), from_center)


    for i in range(width):
        for j in range(height):
            pixel = np.dot(rotation_matrix, [i, j, 1])
            if -1 < pixel[0] < width and -1 < pixel[1] < height:
                rotated_img[i][j] = img[int(pixel[0])][int(pixel[1])]

    return rotated_img
```

In [77]:
```
img = Image.open(file)
x = np.asarray(img.convert('L'))

fig = plt.figure()
fig.add_subplot(1, 2, 1)
plt.imshow(img)
plt.title('Original Image')
fig.add_subplot(1, 2, 2)
plt.imshow(Rotate2D(x, 45))
plt.title('Rotated Image')
plt.show()
```



Translate2D

In [78]:
```
def Translate2D(img, translation):
    width, height = img.shape
    c, r = translation
    translated_img = np.zeros((width, height), dtype=int)

    translated_matrix = np.array([[1, 0, -r], [0, 1, -c]])

    for i in range(width):
        for j in range(height):
            pixel = np.dot(translated_matrix, [i, j, 1])
            if -1 < pixel[0] < width and -1 < pixel[1] < height:
                translated_img[i][j] = img[int(pixel[0])][int(pixel[1])]

    return translated_img
```

In [79]:
```
fig = plt.figure()
fig.add_subplot(1, 2, 1)
plt.imshow(img)
plt.title('Original Image')
fig.add_subplot(1, 2, 2)
plt.imshow(Translate2D(x, [30, -70]))
plt.title('Translated Image')
plt.show()
```