Histogram Equalization and Structural Similarity Index | ENGS 89

Complied and Edited by William L. Roussell

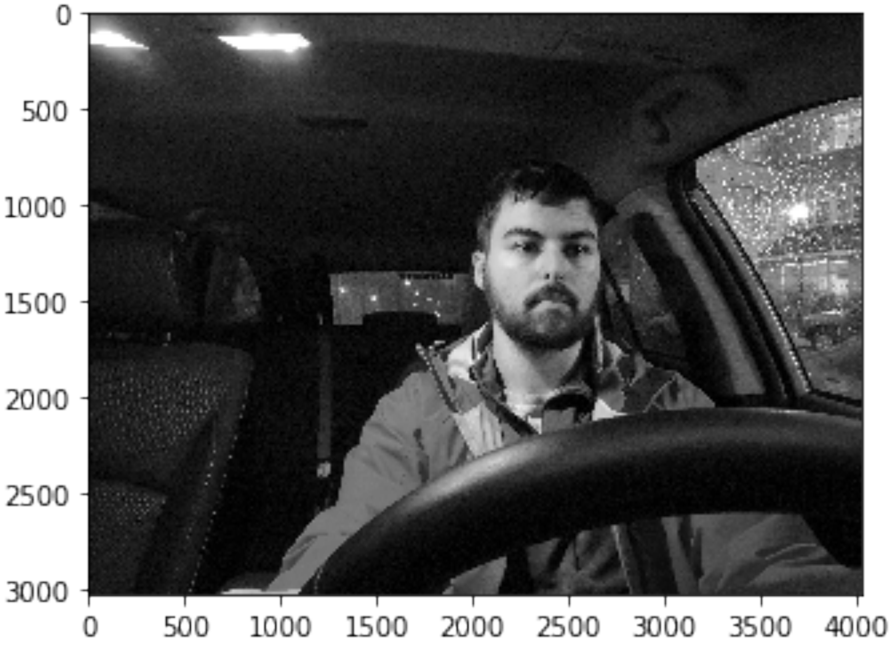
Much of this code is recycled from: https://github.com/torywalker/histogram-equalizer/blob/master/HistogramEqualization.ipynb (https://github.com/torywalker/histogram-equalizer/blob/master/HistogramEqualization.ipynb) and https://scikit-image.org/docs/dev/auto_examples/transform/plot_ssim.html (https://scikit-image.org/docs/dev/auto_examples/transform/plot_ssim.html)

In [1]:

```
%matplotlib inline
from IPython.display import display, Math, Latex

import numpy as np
import matplotlib.pyplot as plt
from PIL import Image

from skimage import data, img_as_float
from skimage import measure
```

In [2]:

```
img = Image.open('Downloads/testImage.jpg').convert("L")
img = np.asarray(img)
img1 = img
plt.imshow(img, cmap='gray')
plt.show()
```

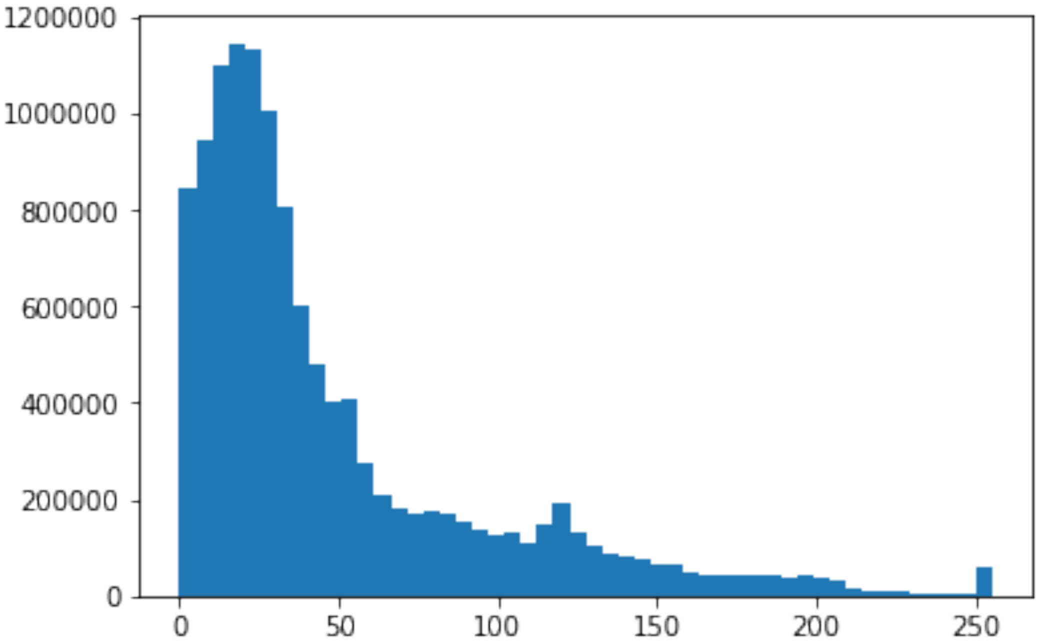


In [3]:

```
# put pixels in a 1D array by flattening out img array
flat = img.flatten()

# show the histogram
plt.hist(flat, bins=50)
```

Out[3]:

```
(array([ 843071.,  943637., 1100331., 1145207., 1133
614., 1003403.,
         803696.,  602561.,  478423.,  400205.,  408
159.,  272766.,
         210995.,  181767.,  172917.,  173239.,  170
744.,  153799.,
         138923.,  124807.,  132249.,  109769.,  147
433.,  190788.,
         133815.,  104581.,   88278.,   80502.,   74
181.,   64384.,
          65093.,   46645.,   42856.,   41043.,   41
131.,   41288.,
          41498.,   39928.,   42953.,   39665.,   33
024.,   14974.,
          11756.,   12002.,    9958.,    6292.,    4
398.,    3837.,
           3996.,   62187.]),
 array([  0. ,   5.1,  10.2,  15.3,  20.4,  25.5,  3
0.6,  35.7,  40.8,
         45.9,  51. ,  56.1,  61.2,  66.3,  71.4,  7
6.5,  81.6,  86.7,
         91.8,  96.9, 102. , 107.1, 112.2, 117.3, 12
2.4, 127.5, 132.6,
        137.7, 142.8, 147.9, 153. , 158.1, 163.2, 16
8.3, 173.4, 178.5,
        183.6, 188.7, 193.8, 198.9, 204. , 209.1, 21
4.2, 219.3, 224.4,
        229.5, 234.6, 239.7, 244.8, 249.9, 255. ]),
 <a list of 50 Patch objects>)
```



In [4]:

```
# formula for creating the histogram
display(Math(r'P_x(j) = \sum_{i=0}^{j} P_x(i)'))
```

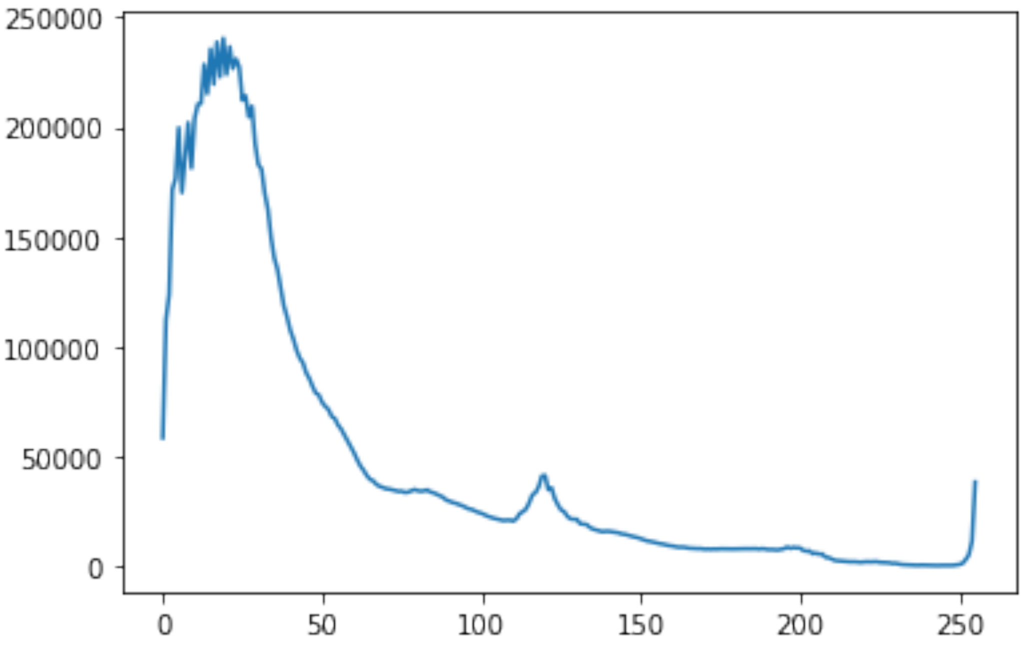
$$P_x(j) = \sum_{i=0}^{j} P_x(i)$$

In [5]:

```
# create our own histogram function
def get_histogram(image, bins):
    # array with size of bins, set to zeros
    histogram = np.zeros(bins)

    # loop through pixels and sum up counts of pixels
    for pixel in image:
        histogram[pixel] += 1

    # return our final result
    return histogram

hist = get_histogram(flat, 256)

plt.plot(hist)
```

Out[5]:

```
[<matplotlib.lines.Line2D at 0x1c25629250>]
```

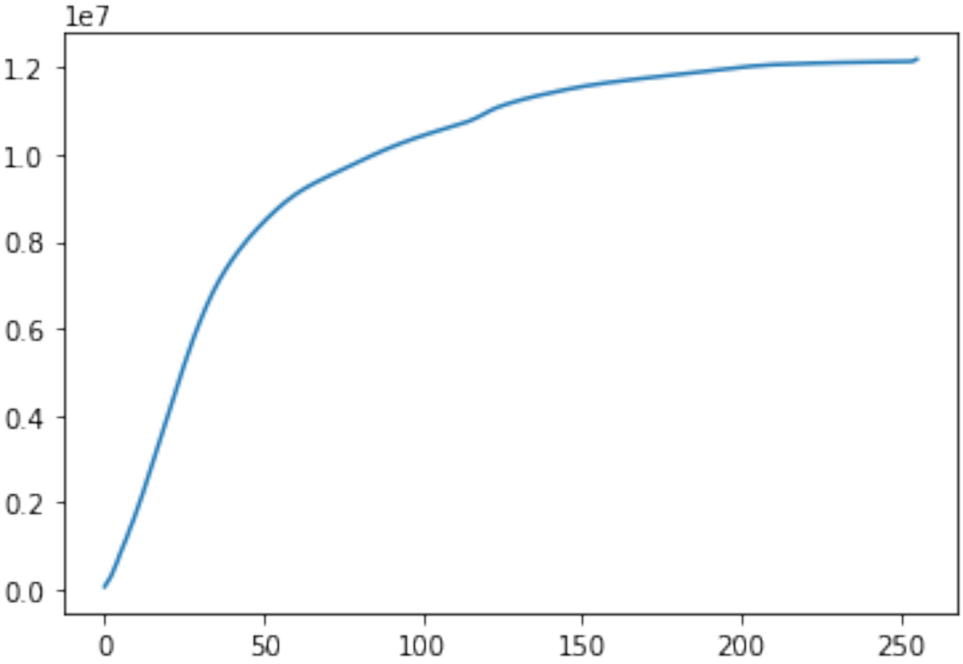


In [6]:

```
# create our cumulative sum function
def cumsum(a):
    a = iter(a)
    b = [next(a)]
    for i in a:
        b.append(b[-1] + i)
    return np.array(b)

# execute the fn
cs = cumsum(hist)

# display the result
plt.plot(cs)
```

Out[6]:

```
[<matplotlib.lines.Line2D at 0x1c25a59a90>]
```



In [7]:

```
# formula to calculate cumulation sum
display(Math(r's_k = \sum_{j=0}^{k} {\frac{n_j}{N}}'))
```

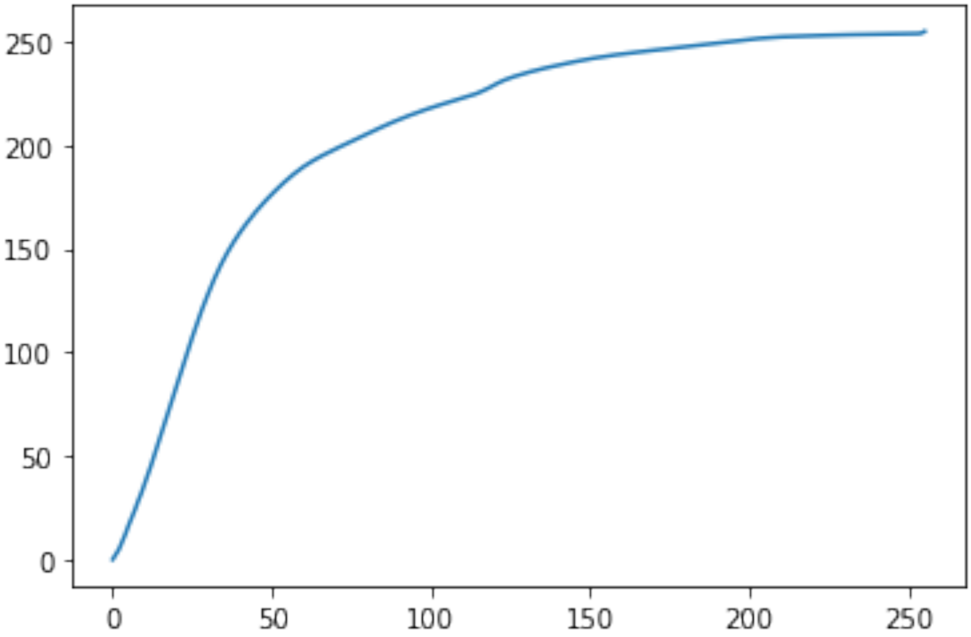
$$s_k = \sum_{j=0}^{k} \frac{n_j}{N}$$

In [8]:

```
# re-normalize cumsum values to be between 0-255

# numerator & denomenator
nj = (cs - cs.min()) * 255
N = cs.max() - cs.min()

# re-normalize the cdf
cs = nj / N

plt.plot(cs)
```

Out[8]:

```
[<matplotlib.lines.Line2D at 0x1c25acf2d0>]
```

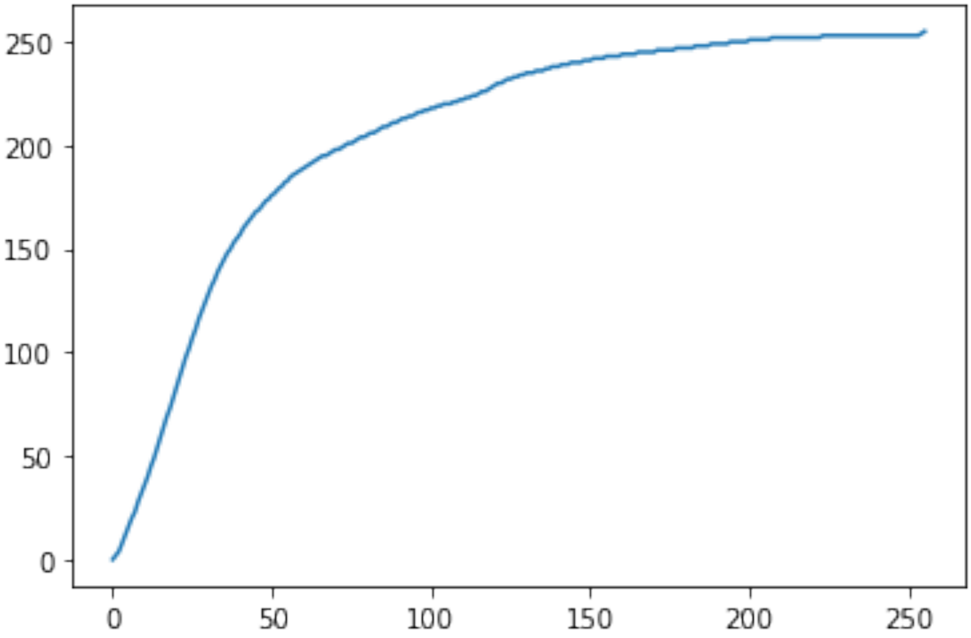


In [9]:

```
# cast it back to uint8 since we can't use floating point values
in images
cs = cs.astype('uint8')

plt.plot(cs)
```

Out[9]:

```
[<matplotlib.lines.Line2D at 0x1c25b2ef50>]
```

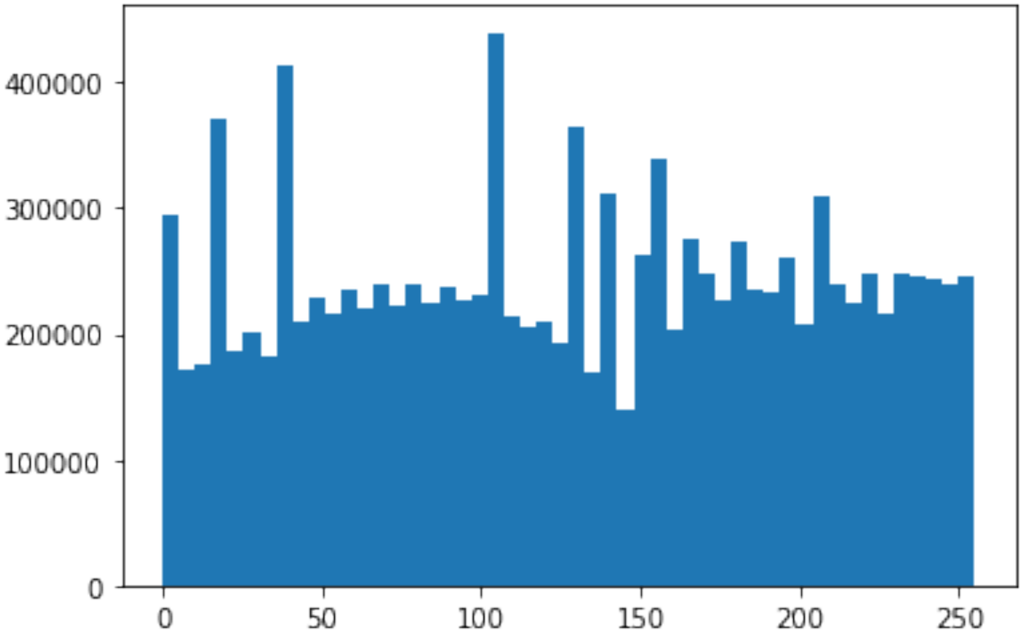


In [10]:

```
# get the value from cumulative sum for every index in flat, and
set that as img_new
img_new = cs[flat]

# we see a much more evenly distributed histogram
plt.hist(img_new, bins=50)
```

Out[10]:

```
(array([295066., 171687., 176591., 369926., 186105.,
202044., 181339.,
        414321., 210695., 228527., 215211., 235527.,
219466., 238653.,
        222798., 240414., 223876., 236557., 226573.,
230979., 439505.,
        214138., 204584., 209451., 192323., 363830.,
169973., 312336.,
        140464., 262379., 340182., 202260., 276163.,
247071., 226215.,
        272362., 234603., 232671., 260970., 206988.,
309912., 239117.,
        224094., 247875., 215425., 248715., 245305.,
243665., 238795.,
        245042.]),
 array([  0. ,   5.1,  10.2,  15.3,  20.4,  25.5,  3
0.6,  35.7,  40.8,
         45.9,  51. ,  56.1,  61.2,  66.3,  71.4,  7
6.5,  81.6,  86.7,
         91.8,  96.9, 102. , 107.1, 112.2, 117.3, 12
2.4, 127.5, 132.6,
        137.7, 142.8, 147.9, 153. , 158.1, 163.2, 16
8.3, 173.4, 178.5,
        183.6, 188.7, 193.8, 198.9, 204. , 209.1, 21
4.2, 219.3, 224.4,
        229.5, 234.6, 239.7, 244.8, 249.9, 255. ]),
 <a list of 50 Patch objects>)
```



In [11]:

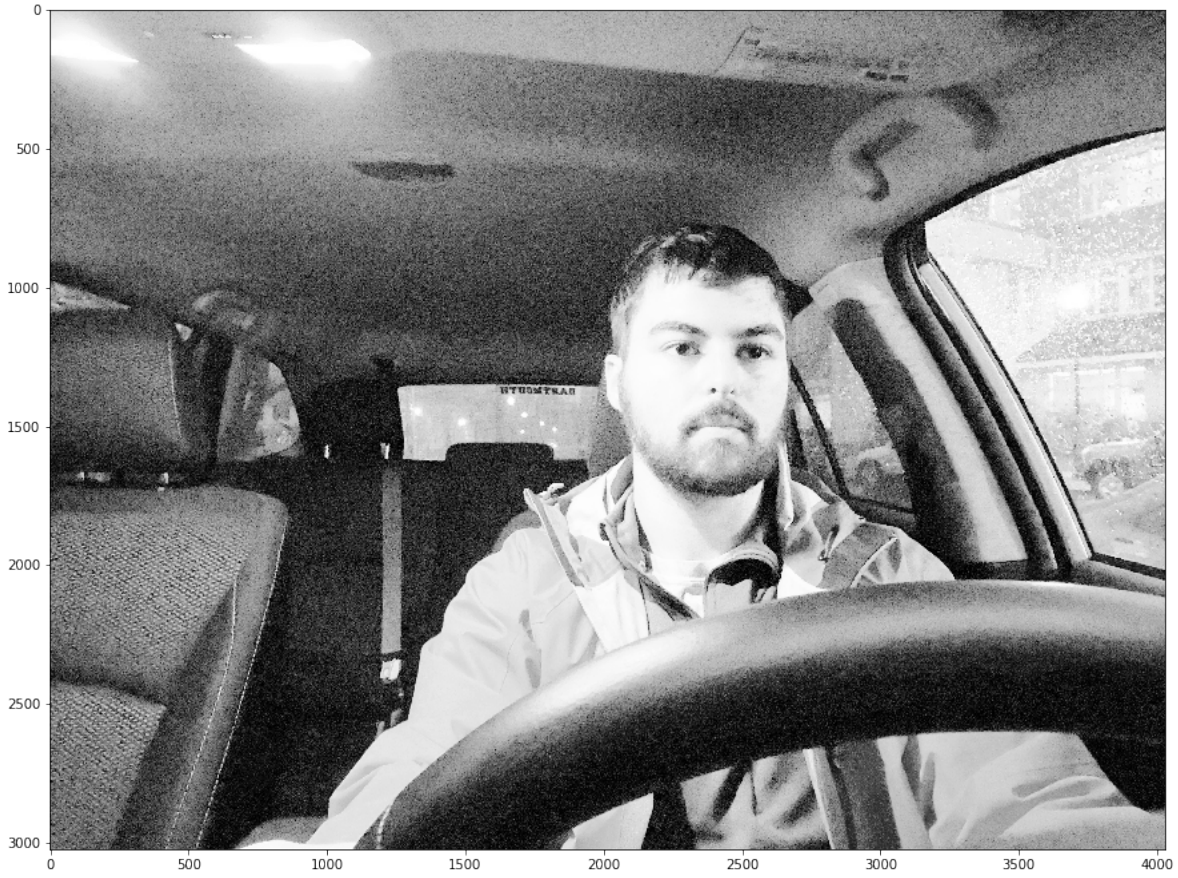
```
# put array back into original shape since we flattened it
img_new = np.reshape(img_new, img.shape)
img2 = img_new
img_new
```

Out[11]:

```
array([[226, 223, 220, ..., 111, 128, 135],
       [222, 220, 218, ...,  98, 107, 107],
       [220, 217, 218, ...,  83,  83,  83],
       ...,
       [162, 142, 111, ..., 155, 157, 160],
       [ 88, 107,  93, ..., 157, 162, 153],
       [ 28,  83,  88, ..., 174, 180, 166]], dtype=u
int8)
```

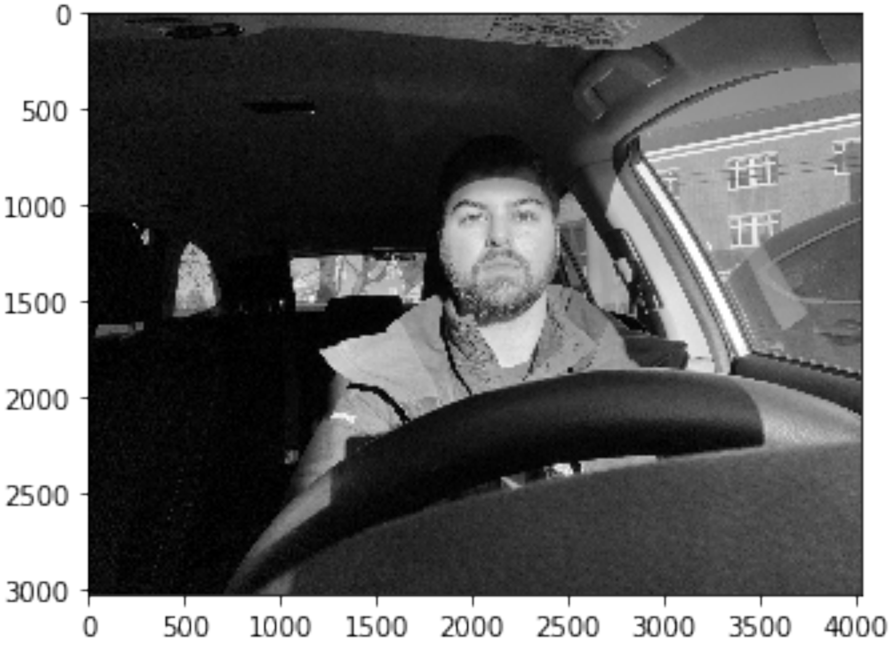
In [12]:

```
# set up side-by-side image display
fig = plt.figure()
fig.set_figheight(15)
fig.set_figwidth(15)

#fig.add_subplot(1,2,1)
#plt.imshow(img, cmap='gray')

# display the new image
#fig.add_subplot(1,2,2)
plt.imshow(img_new, cmap='gray')

plt.show(block=True)
```



In [13]:

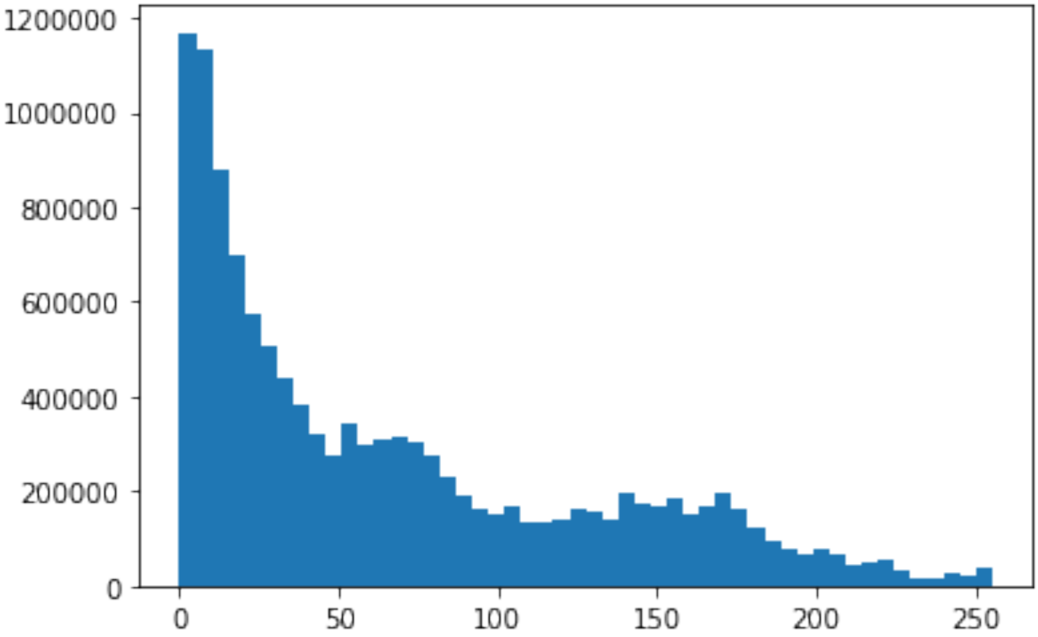
```
imgd = Image.open('Downloads/testImage2.jpg').convert("L")
imgd = np.asarray(imgd)
img3 = imgd
plt.imshow(imgd, cmap='gray')
plt.show()
```



In [14]:

```
# put pixels in a 1D array by flattening out img array
flatd = imgd.flatten()

# show the histogram
plt.hist(flatd, bins=50)
```

```
Out[14]:

(array([1168181., 1135274.,  876824.,  699076.,  576
207.,  507342.,
         438269.,  383648.,  319339.,  275830.,  340
866.,  299362.,
         308283.,  317407.,  305512.,  273421.,  230
524.,  189134.,
         164947.,  150608.,  165422.,  133481.,  135
703.,  139481.,
         163132.,  159616.,  139520.,  193998.,  174
178.,  168578.,
         185738.,  151870.,  168741.,  195260.,  162
158.,  122642.,
          94836.,   75967.,   66449.,   77138.,   66
640.,   45392.,
          47882.,   56921.,   31815.,   14774.,   15
354.,   24480.,
          19193.,   36355.]),
 array([  0. ,   5.1,  10.2,  15.3,  20.4,  25.5,  3
0.6,  35.7,  40.8,
         45.9,  51. ,  56.1,  61.2,  66.3,  71.4,  7
6.5,  81.6,  86.7,
         91.8,  96.9, 102. , 107.1, 112.2, 117.3, 12
2.4, 127.5, 132.6,
        137.7, 142.8, 147.9, 153. , 158.1, 163.2, 16
8.3, 173.4, 178.5,
        183.6, 188.7, 193.8, 198.9, 204. , 209.1, 21
4.2, 219.3, 224.4,
        229.5, 234.6, 239.7, 244.8, 249.9, 255. ]),
 <a list of 50 Patch objects>)
```



In [15]:

```
# formula for creating the histogram
display(Math(r'P_x(j) = \sum_{i=0}^{j} P_x(i)'))
```

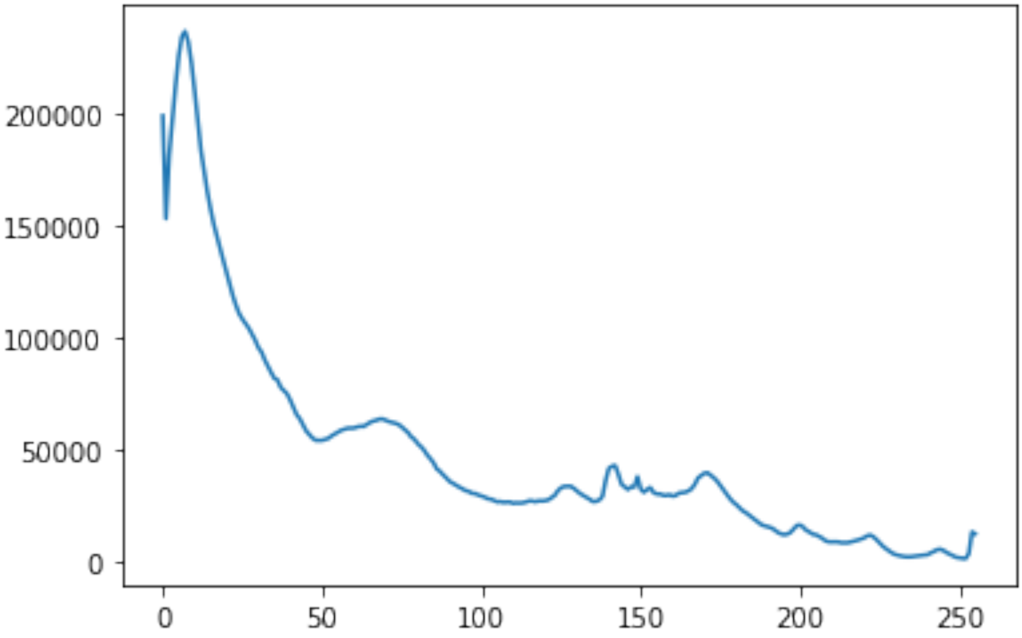
$$P_x(j) = \sum_{i=0}^{j} P_x(i)$$

In [16]:

```
# create our own histogram function
def get_histogram(image, bins):
    # array with size of bins, set to zeros
    histogram = np.zeros(bins)

    # loop through pixels and sum up counts of pixels
    for pixel in image:
        histogram[pixel] += 1

    # return our final result
    return histogram

histd = get_histogram(flatd, 256)

plt.plot(histd)
```

Out[16]:

```
[<matplotlib.lines.Line2D at 0x1c26349390>]
```

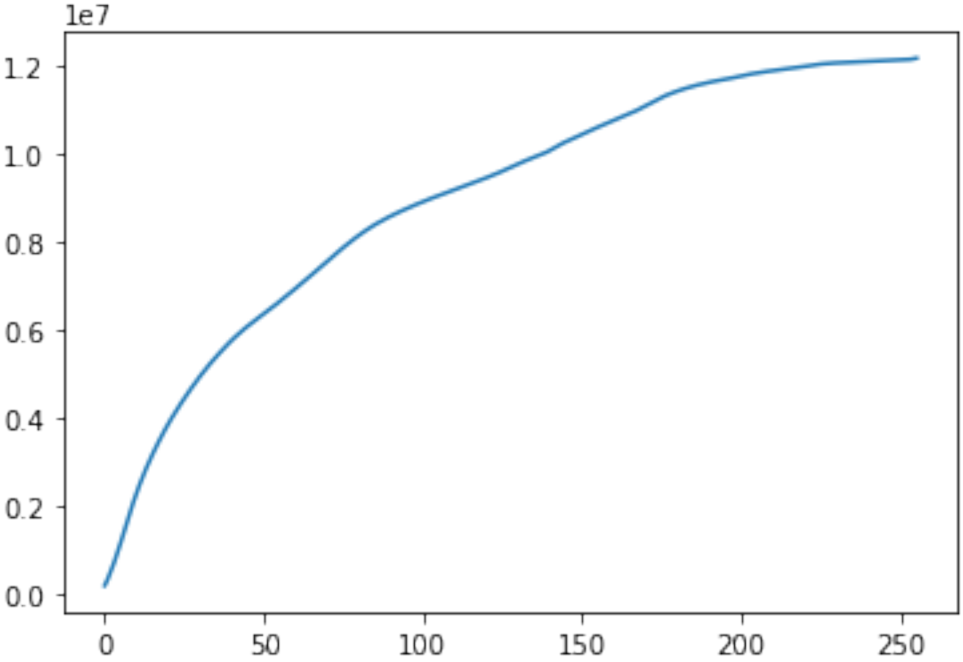


In [17]:

```
# create our cumulative sum function
def cumsum(a):
    a = iter(a)
    b = [next(a)]
    for i in a:
        b.append(b[-1] + i)
    return np.array(b)

# execute the fn
csd = cumsum(histd)

# display the result
plt.plot(csd)
```

Out[17]:

```
[<matplotlib.lines.Line2D at 0x1c263ae950>]
```



In [18]:

```
# formula to calculate cumulation sum
display(Math(r's_k = \sum_{j=0}^{k} {\frac{n_j}{N}}'))
```

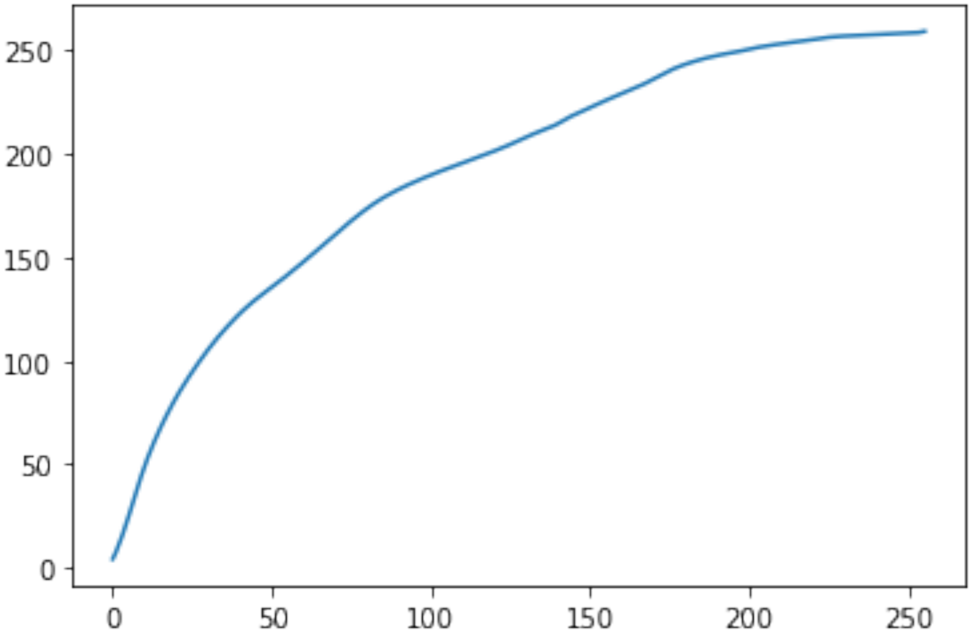
$$s_k = \sum_{j=0}^{k} \frac{n_j}{N}$$

In [19]:

```
# re-normalize cumsum values to be between 0-255

# numerator & denomenator
njd = (csd - cs.min()) * 255
Nd = csd.max() - csd.min()

# re-normalize the cdf
csd = njd / Nd

plt.plot(csd)
```

Out[19]:

```
[<matplotlib.lines.Line2D at 0x1c25831c90>]
```

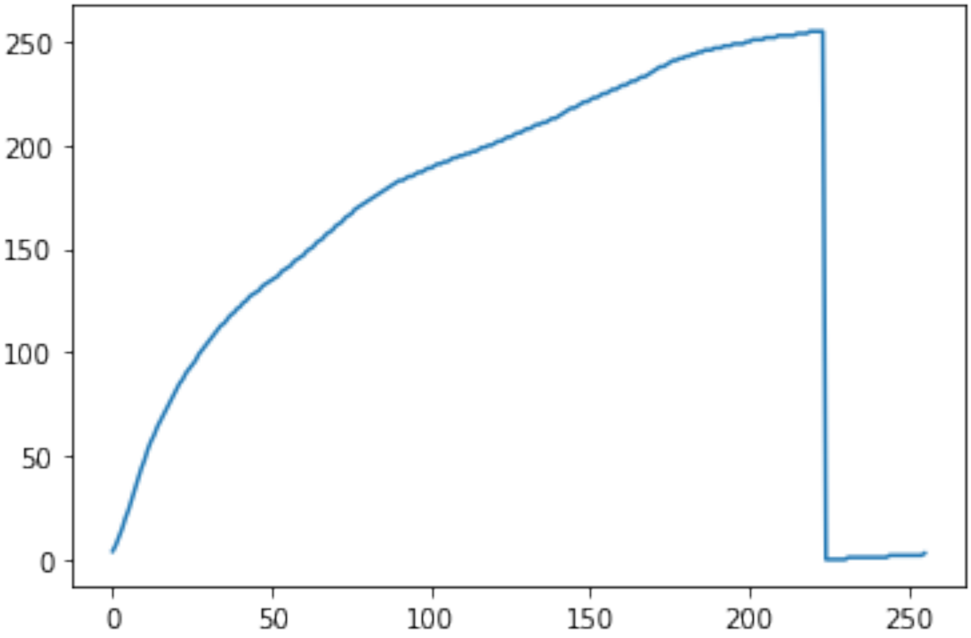


In [20]:

```
# cast it back to uint8 since we can't use floating point values in images
csd = csd.astype('uint8')

plt.plot(csd)
```

Out[20]:

```
[<matplotlib.lines.Line2D at 0x1c26410590>]
```

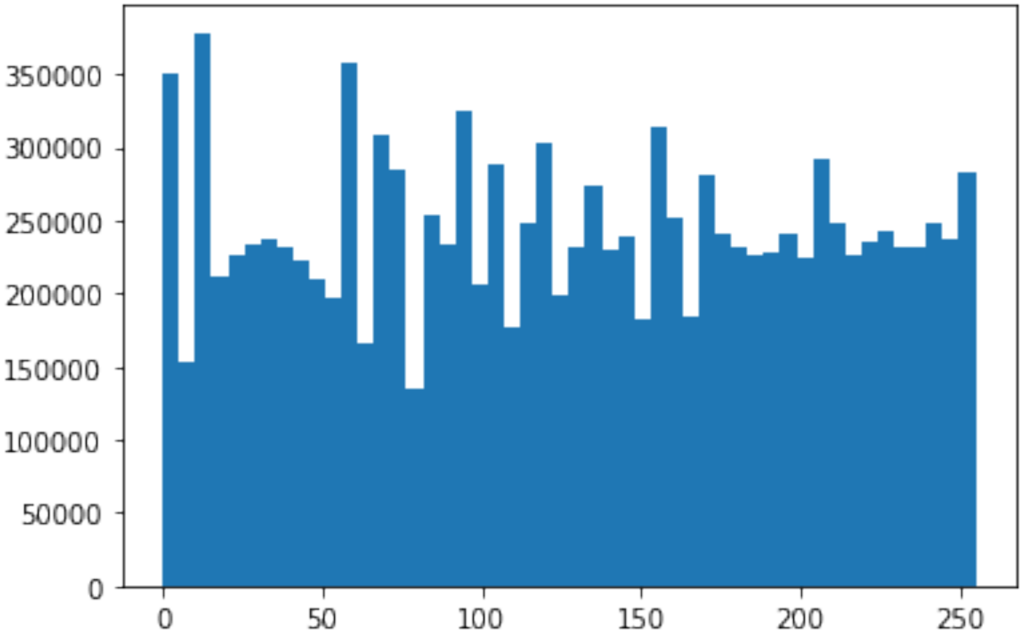


In [21]:

```
# get the value from cumulative sum for every index in flat, and set that as img_new
img_newd = csd[flatd]

# we see a much more evenly distributed histogram
plt.hist(img_newd, bins=50)
```

Out[21]:

```
(array([351213., 153137., 378369., 212187., 225540.,
234263., 236549.,
        231862., 222500., 210100., 196535., 357789.,
165049., 308124.,
        284522., 134572., 253064., 233234., 325598.,
206142., 288605.,
        177670., 248176., 302286., 199276., 232537.,
273649., 230573.,
        238949., 181746., 314216., 252612., 183962.,
280783., 240491.,
        230884., 226583., 227593., 241444., 223934.,
292836., 247407.,
        226537., 235774., 242055., 230850., 231548.,
248512., 237252.,
        283679.]),
 array([  0. ,   5.1,  10.2,  15.3,  20.4,  25.5,  3
0.6,  35.7,  40.8,
         45.9,  51. ,  56.1,  61.2,  66.3,  71.4,  7
6.5,  81.6,  86.7,
         91.8,  96.9, 102. , 107.1, 112.2, 117.3, 12
2.4, 127.5, 132.6,
        137.7, 142.8, 147.9, 153. , 158.1, 163.2, 16
8.3, 173.4, 178.5,
        183.6, 188.7, 193.8, 198.9, 204. , 209.1, 21
4.2, 219.3, 224.4,
        229.5, 234.6, 239.7, 244.8, 249.9, 255. ]),
 <a list of 50 Patch objects>)
```



In [22]:

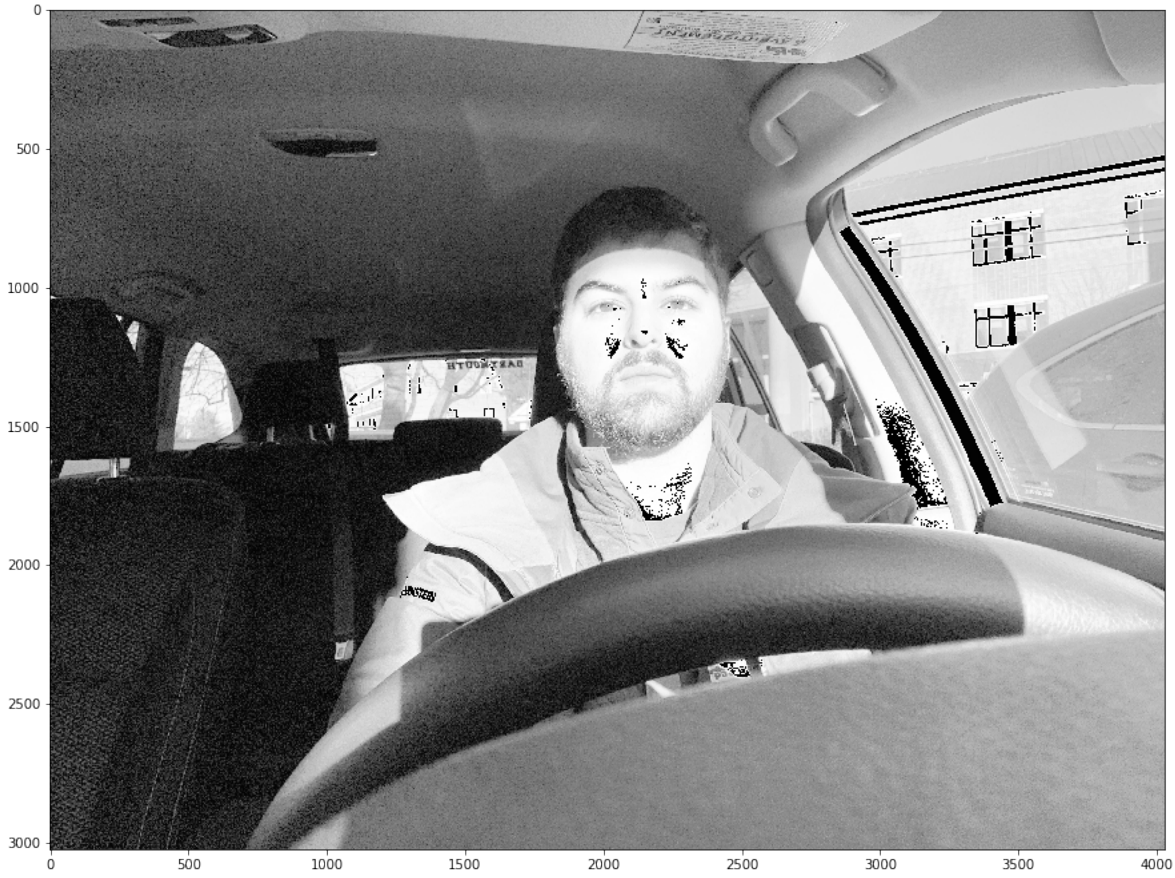
```
# put array back into original shape since we flattened it
img_newd = np.reshape(img_newd, imgd.shape)
img4 = img_newd
img_newd
```

Out[22]:

```
array([[111,  99, 113, ..., 142, 142, 141],
       [119,  82, 107, ..., 142, 142, 140],
       [107,  85, 114, ..., 144, 144, 141],
       ...,
       [ 60,  39,  44, ..., 166, 170, 172],
       [ 67,  60,  57, ..., 171, 169, 166],
       [ 67,  48,  53, ..., 166, 171, 175]], dtype=u
int8)
```

In [23]:

```
# set up side-by-side image display
fig = plt.figure()
fig.set_figheight(15)
fig.set_figwidth(15)

#fig.add_subplot(1,2,1)
#plt.imshow(img, cmap='gray')

# display the new image
#fig.add_subplot(1,2,2)
plt.imshow(img_newd, cmap='gray')

plt.show(block=True)
```



In [24]:

```
# Here is our structural similarity index for the images that did not undergo histogram equalization.
s1 = measure.compare_ssim(img1, img3)
s1
```

Out[24]:

```
0.3177184912917075
```

In [25]:

```
# Here is our structural similarity index for the images that did undergo histogram equalization.
s2 = measure.compare_ssim(img2, img4)
s2
```

Out[25]:

```
0.1752029567601612
```