# assignment07

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### 0.0.1 K-means clustering on image value and its spatial domain

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In [47]:
```
import PIL.Image as pilimg
import matplotlib.pyplot as plt
import numpy as np
import random

file_data                = pilimg.open("building.jpg")
data                        = np.array(file_data)
modifiedData                            = np.array(file_data)

size_col        = len(data[0]) # height of the image
size_row          = len(data)    # width of the image
size_rgb        = 3            # Red, Green, Blue

x_matrix = np.empty((size_row, size_col), dtype=float)
y_matrix = np.empty((size_row, size_col), dtype=float)

average = np.zeros(size_rgb, dtype = float)
deviation = np.zeros(size_rgb, dtype = float)

for i in range(0, size_row):
    for j in range(0, size_col):
        x_matrix[i][j] = j
        y_matrix[i][j] = i

for i in range(0, size_row):
    for j in range(0, size_col):
        average += data[i][j]
average = average / (size_row * size_col)

for i in range(0, size_row):
    for j in range(0, size_col):
        deviation += (data[i][j] - average) ** 2
```

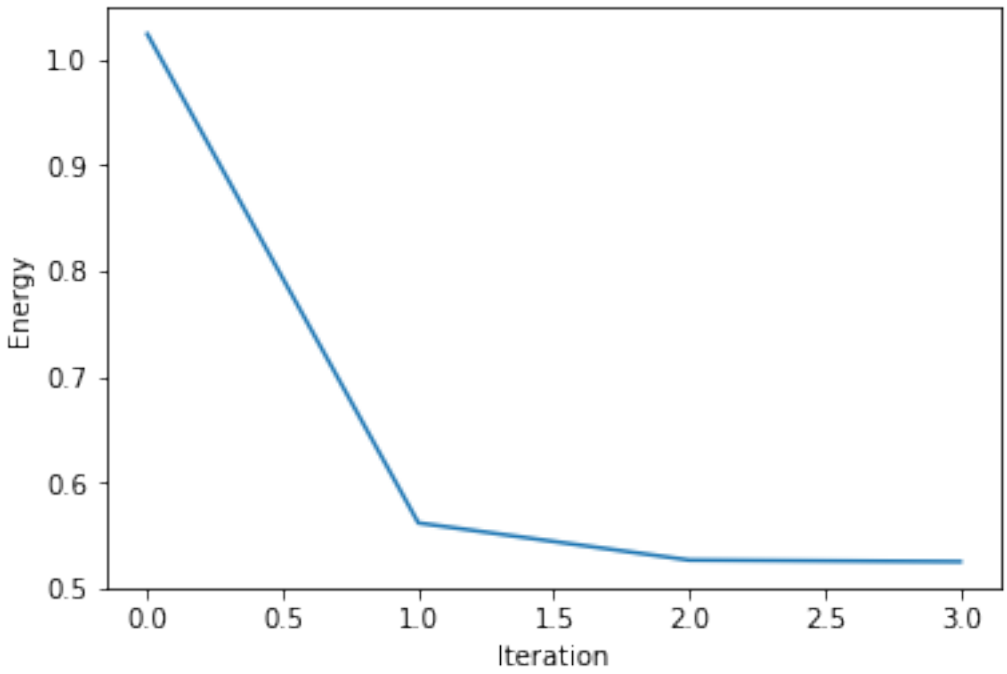
```
deviation = np.sqrt(deviation / (size_row * size_col))


#
# linear scaling
#
for i in range(0, size_row):
    for j in range(0, size_col):
        x_matrix[i][j] /= size_col - 1
        y_matrix[i][j] /= size_row - 1


#
# image whitening
#
for i in range(0, size_row):
    for j in range(0, size_col):
        data[i][j] = abs((data[i][j] - average)) / deviation

#
# normalize the values of the input data to be [0, 1]
#
def normalize(data):

    data_normalized = (data - min(data)) / (max(data) - min(data))

    return(data_normalized)

#
# example of distance function between two vectors x and y
#
def l2_distance(x, y):

    d = (x - y) ** 2
    s = np.sum(d)
    #r = np.sqrt(s)

    return(s)

#
# example of distance function between two vectors x and y
#
def l1_distance(x, y):

    d = abs(x - y)
    s = np.sum(d)

    return(s)
```

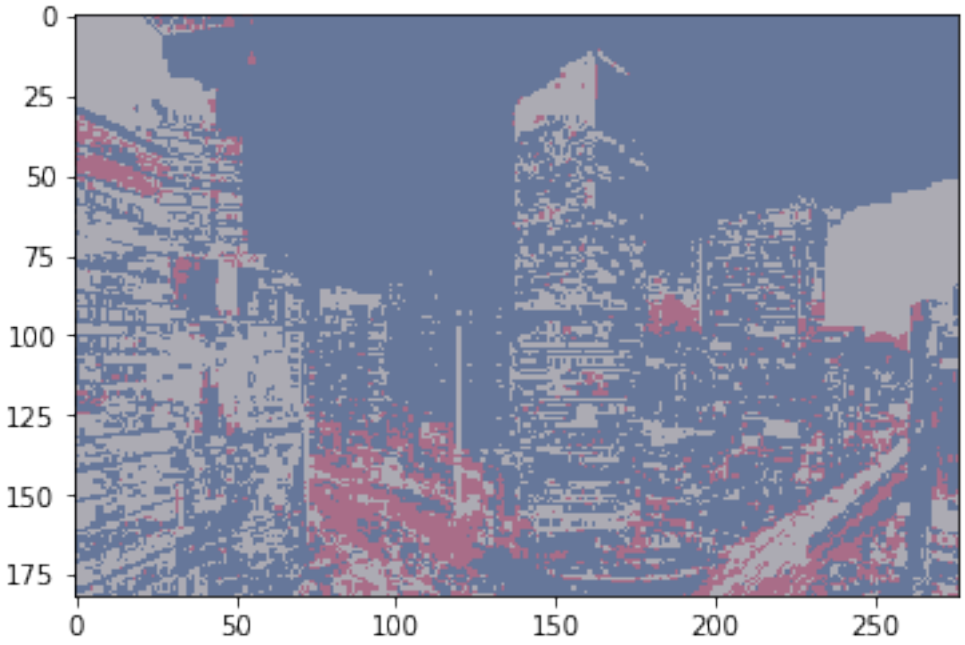
### 0.0.4 k = 3, a = 1

In [50]:
```
k = 3
a = 1
EnergyList = []

rgb_list_centroid = np.zeros((k, size_rgb), dtype=float)
rgb_list_count    = np.zeros(k)

x_list_centroid = np.zeros(k, dtype=float)
x_list_count    = np.zeros(k)
y_list_centroid = np.zeros(k, dtype=float)
y_list_count    = np.zeros(k)

list_label    = np.empty((size_row, size_col), dtype=int)

for i in range(size_row):
    for j in range(size_col):
        label       = random.randint(0, k - 1)
        list_label[i][j]       = label
        rgb_list_centroid[label, :]+= data[i][j]
        rgb_list_count[label]      += 1
        x_list_centroid[label]+= x_matrix[i][j]
        x_list_count[label]      += 1
        y_list_centroid[label]+= y_matrix[i][j]
        y_list_count[label]      += 1

for i in range(0, k):
    rgb_list_centroid[i, :] /= rgb_list_count[i]
    x_list_centroid[i] /= x_list_count[i]
    y_list_centroid[i] /= y_list_count[i]


while True:
    checkUpdate = 0
    Energy = 0
    for i in range(size_row):
        for j in range(size_col):
            label = list_label[i][j]
            min = (l2_distance(x_list_centroid[label], x_matrix[i][j]) + l2_distance(y
            Energy += min
            for m in range(k):
                if m == label:
                    continue

                checkDistance = (l2_distance(x_list_centroid[m], x_matrix[i][j]) + l2
                if(min > checkDistance):
                    list_label[i][j] = m
```

```
                    min = checkDistance
                    checkUpdate += 1
        Energy = Energy / (size_row * size_col)
        EnergyList.append(Energy)

        if(checkUpdate == 0):
            break

        rgb_list_centroid = np.zeros((k, size_rgb), dtype=float)
        rgb_list_count = np.zeros(k)
        x_list_centroid = np.zeros(k, dtype=float)
        y_list_centroid = np.zeros(k, dtype=float)
        x_list_count = np.zeros(k)
        y_list_count = np.zeros(k)

        for i in range(size_row):
            for j in range(size_col):
                label = list_label[i][j]
                rgb_list_centroid[label, :] += data[i][j]
                rgb_list_count[label]       += 1
                x_list_centroid[label]  += x_matrix[i][j]
                y_list_centroid[label]  += y_matrix[i][j]
                x_list_count[label]     += 1
                y_list_count[label]     += 1

        for i in range(0, k):
            rgb_list_centroid[i, :] /= rgb_list_count[i]
            x_list_centroid[i]  /= x_list_count[i]
            y_list_centroid[i]  /= y_list_count[i]


    #
    # image reverse whitening
    #
    for i in range(0, k):
            rgb_list_centroid[i, :] = (rgb_list_centroid[i, :] * deviation) + average


    #
    # plot image & energy
    #
    x = np.arange(0, len(EnergyList), 1)
    plt.plot(x, EnergyList)
    plt.xlabel('Iteration')
    plt.ylabel('Energy')
    plt.show()

    for i in range(size_row):
```

```
    for j in range(size_col):
        label      = list_label[i][j]
        modifiedData[i][j] = rgb_list_centroid[label, :]
plt.imshow(modifiedData)
plt.show()
```



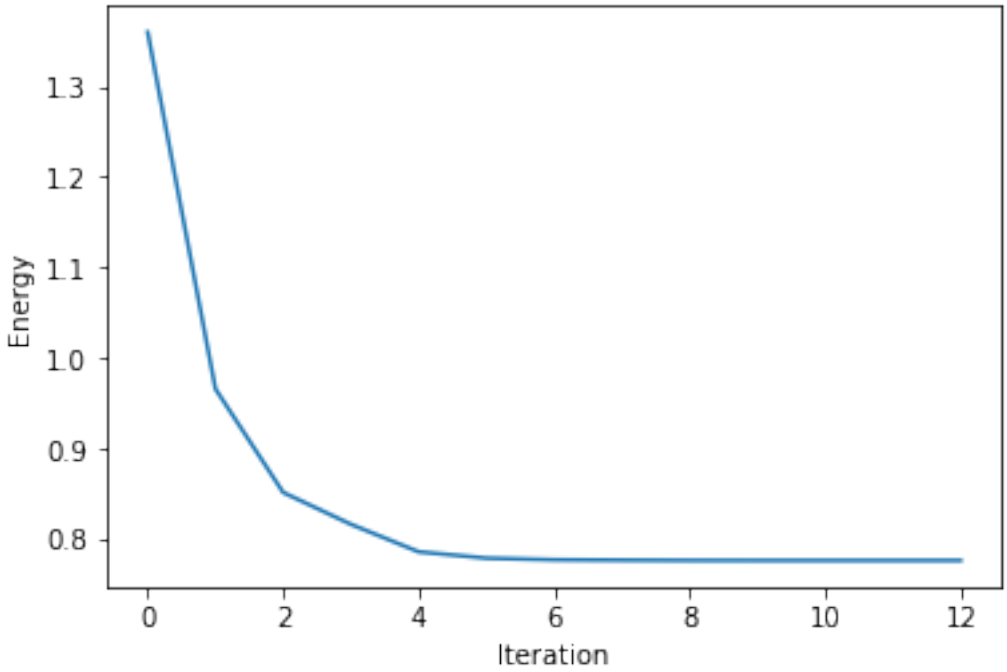



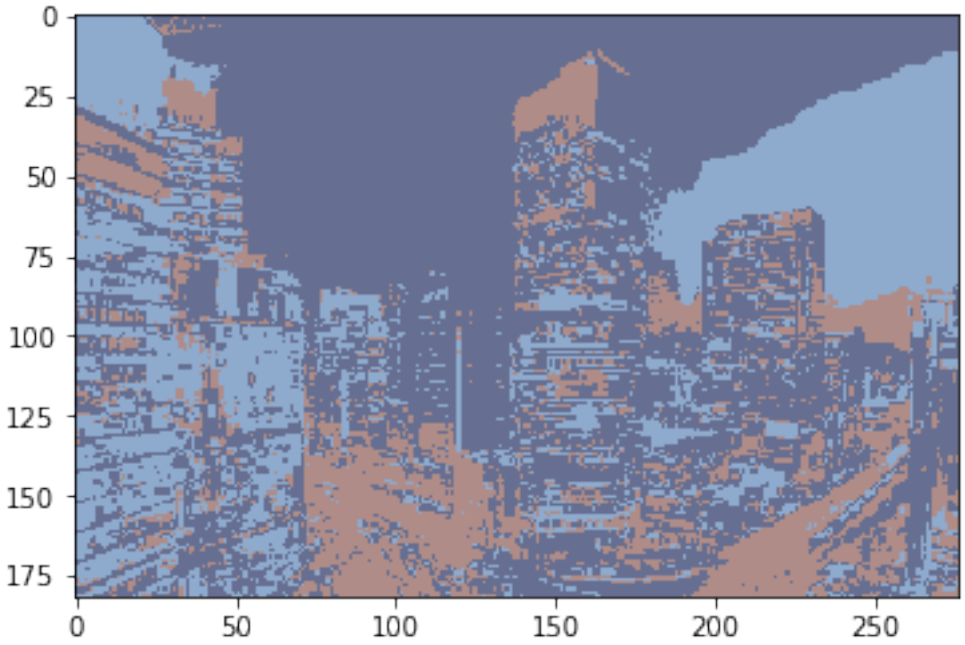
#### 0.0.5 k = 3, a = 3

In [52]:
```
k = 3
a = 3
EnergyList = []

rgb_list_centroid = np.zeros((k, size_rgb), dtype=float)
rgb_list_count    = np.zeros(k)

x_list_centroid = np.zeros(k, dtype=float)
x_list_count    = np.zeros(k)
y_list_centroid = np.zeros(k, dtype=float)
y_list_count    = np.zeros(k)

list_label    = np.empty((size_row, size_col), dtype=int)

for i in range(size_row):
    for j in range(size_col):
        label       = random.randint(0, k - 1)
        list_label[i][j]       = label
        rgb_list_centroid[label, :]+= data[i][j]
        rgb_list_count[label]      += 1
        x_list_centroid[label]+= x_matrix[i][j]
        x_list_count[label]      += 1
        y_list_centroid[label]+= y_matrix[i][j]
        y_list_count[label]      += 1

for i in range(0, k):
    rgb_list_centroid[i, :] /= rgb_list_count[i]
    x_list_centroid[i] /= x_list_count[i]
    y_list_centroid[i] /= y_list_count[i]


while True:
    checkUpdate = 0
    Energy = 0
    for i in range(size_row):
        for j in range(size_col):
            label = list_label[i][j]
            min = (l2_distance(x_list_centroid[label], x_matrix[i][j]) + l2_distance(y
            Energy += min
            for m in range(k):
                if m == label:
                    continue
```

```
                checkDistance = (l2_distance(x_list_centroid[m], x_matrix[i][j]) + l2_
                if(min > checkDistance):
                    list_label[i][j] = m
                    min = checkDistance
                    checkUpdate += 1
    Energy = Energy / (size_row * size_col)
    EnergyList.append(Energy)

    if(checkUpdate == 0):
        break

    rgb_list_centroid = np.zeros((k, size_rgb), dtype=float)
    rgb_list_count = np.zeros(k)
    x_list_centroid = np.zeros(k, dtype=float)
    y_list_centroid = np.zeros(k, dtype=float)
    x_list_count = np.zeros(k)
    y_list_count = np.zeros(k)

    for i in range(size_row):
        for j in range(size_col):
            label = list_label[i][j]
            rgb_list_centroid[label, :] += data[i][j]
            rgb_list_count[label]       += 1
            x_list_centroid[label]  += x_matrix[i][j]
            y_list_centroid[label]  += y_matrix[i][j]
            x_list_count[label]     += 1
            y_list_count[label]     += 1

    for i in range(0, k):
        rgb_list_centroid[i, :] /= rgb_list_count[i]
        x_list_centroid[i]  /= x_list_count[i]
        y_list_centroid[i]  /= y_list_count[i]


#
# image reverse whitening
#
for i in range(0, k):
        rgb_list_centroid[i, :] = (rgb_list_centroid[i, :] * deviation) + average


#
# plot image & energy
#
x = np.arange(0, len(EnergyList), 1)
plt.plot(x, EnergyList)
plt.xlabel('Iteration')
plt.ylabel('Energy')
```

```
plt.show()

for i in range(size_row):
    for j in range(size_col):
        label      = list_label[i][j]
        modifiedData[i][j] = rgb_list_centroid[label, :]
plt.imshow(modifiedData)
plt.show()
```



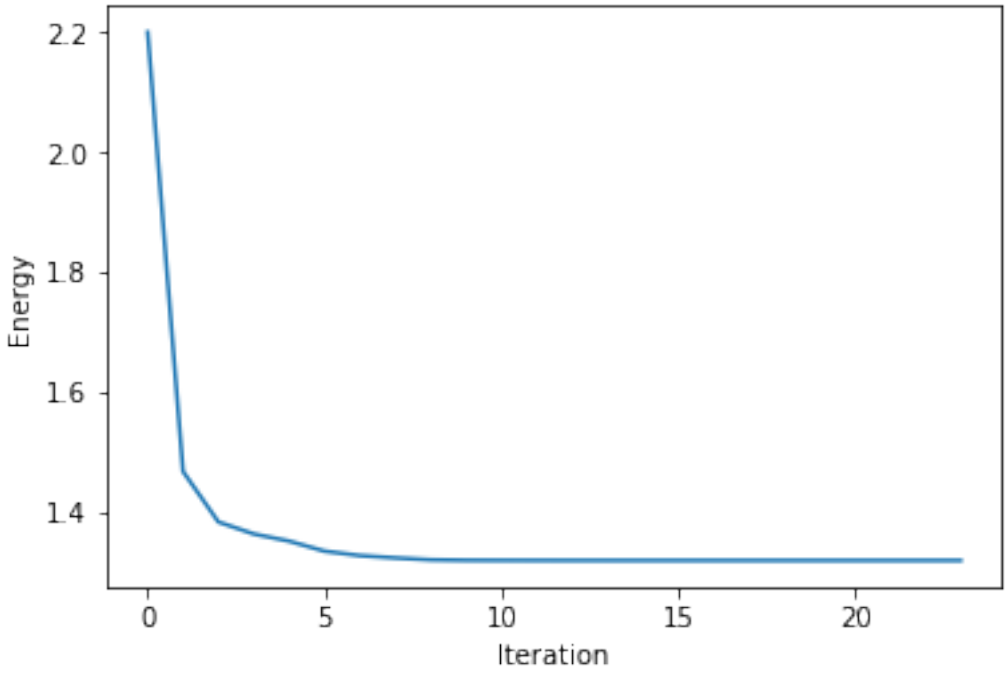


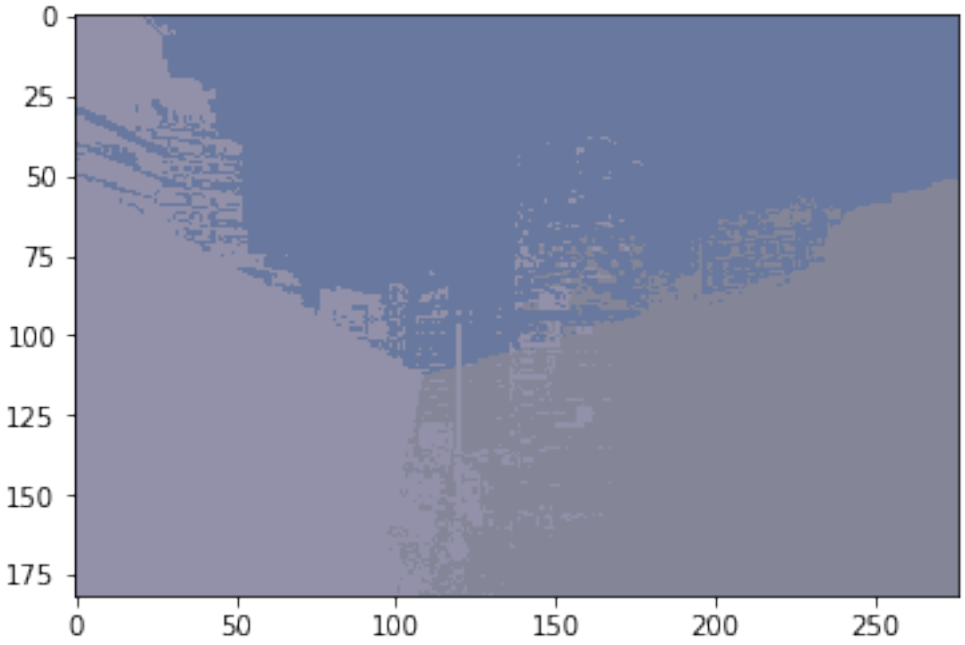

### 0.0.6 k = 3, a = 8

```
In [53]: k = 3
         a = 8
         EnergyList = []

         rgb_list_centroid = np.zeros((k, size_rgb), dtype=float)
         rgb_list_count    = np.zeros(k)

         x_list_centroid = np.zeros(k, dtype=float)
         x_list_count    = np.zeros(k)
         y_list_centroid = np.zeros(k, dtype=float)
         y_list_count    = np.zeros(k)

         list_label    = np.empty((size_row, size_col), dtype=int)

         for i in range(size_row):
             for j in range(size_col):
                 label       = random.randint(0, k - 1)
                 list_label[i][j]       = label
                 rgb_list_centroid[label, :]+= data[i][j]
                 rgb_list_count[label]      += 1
                 x_list_centroid[label]+= x_matrix[i][j]
                 x_list_count[label]      += 1
                 y_list_centroid[label]+= y_matrix[i][j]
```

```
        y_list_count[label]      += 1

for i in range(0, k):
    rgb_list_centroid[i, :] /= rgb_list_count[i]
    x_list_centroid[i] /= x_list_count[i]
    y_list_centroid[i] /= y_list_count[i]


while True:
    checkUpdate = 0
    Energy = 0
    for i in range(size_row):
        for j in range(size_col):
            label = list_label[i][j]
            min = (l2_distance(x_list_centroid[label], x_matrix[i][j]) + l2_distance(y
            Energy += min
            for m in range(k):
                if m == label:
                    continue

                checkDistance = (l2_distance(x_list_centroid[m], x_matrix[i][j]) + l2
                if(min > checkDistance):
                    list_label[i][j] = m
                    min = checkDistance
                    checkUpdate += 1
    Energy = Energy / (size_row * size_col)
    EnergyList.append(Energy)

    if(checkUpdate == 0):
        break

    rgb_list_centroid = np.zeros((k, size_rgb), dtype=float)
    rgb_list_count = np.zeros(k)
    x_list_centroid = np.zeros(k, dtype=float)
    y_list_centroid = np.zeros(k, dtype=float)
    x_list_count = np.zeros(k)
    y_list_count = np.zeros(k)

    for i in range(size_row):
        for j in range(size_col):
            label = list_label[i][j]
            rgb_list_centroid[label, :] += data[i][j]
            rgb_list_count[label]       += 1
            x_list_centroid[label]  += x_matrix[i][j]
            y_list_centroid[label]  += y_matrix[i][j]
            x_list_count[label]     += 1
            y_list_count[label]     += 1
```

```
    for i in range(0, k):
        rgb_list_centroid[i, :] /= rgb_list_count[i]
        x_list_centroid[i]  /= x_list_count[i]
        y_list_centroid[i]  /= y_list_count[i]


#
# image reverse whitening
#
for i in range(0, k):
        rgb_list_centroid[i, :] = (rgb_list_centroid[i, :] * deviation) + average


#
# plot image & energy
#
x = np.arange(0, len(EnergyList), 1)
plt.plot(x, EnergyList)
plt.xlabel('Iteration')
plt.ylabel('Energy')
plt.show()

for i in range(size_row):
    for j in range(size_col):
        label      = list_label[i][j]
        modifiedData[i][j] = rgb_list_centroid[label, :]
plt.imshow(modifiedData)
plt.show()
```


2.2
2.0
1.8
1.6
1.4
Energy
0
5
10
15
20
Iteration


0
25
50
75
100
125
150
175
0
50
100
150
200
250