K-means algorithm to both image value and its spatial domain

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Major: **Software Engineering**

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For a given input image (either gray or color), apply a K-means algorithm that is designed to take into consideration of both the image intensity and its spatial domain with varying parameters: the number of clusters and the trade-off between the intensity energy and the spatial energy.

The objective function is given by:

$\sum_k \sum_{\{} x \in I(k)\}[\|f(x) - m_k\|^2 + a * \|x - c_k\|^2]$

where I(k) denotes the index set of x that belongs to cluster k, m_k denotes the centroid of image intensity for cluster k, c_k denotes the centroid of spatial location for cluster k, and a determines the importance between the image intensity and the spatial relation.

- Visualize the clustering results with varying k and a using the centroid color m_k for each cluster k.
- Visualize the energy curve for both the intensity energy and the spatial energy.

0.0.1 Start!

```
In [352]: import matplotlib.pyplot as plt
          from mpl_toolkits.mplot3d import Axes3D
          from random import *
          import numpy as np
          import cv2
          np.set_printoptions(threshold=10)
```

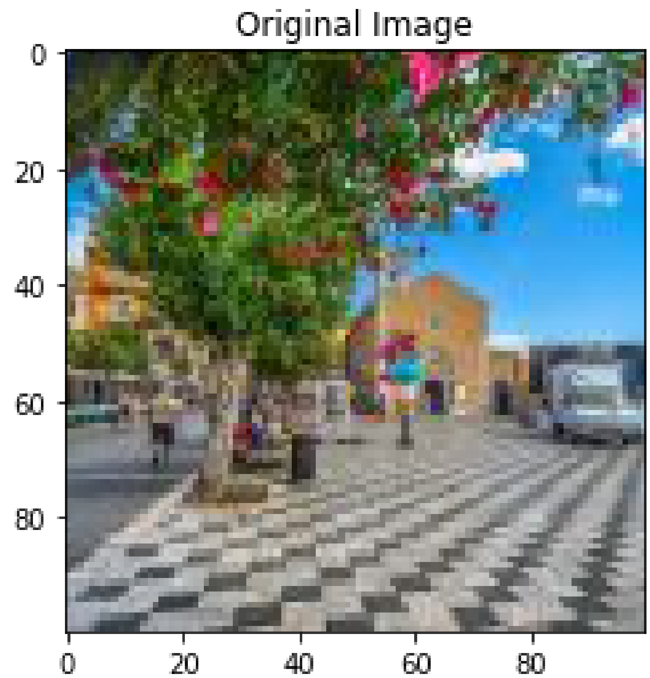
0.0.2 Functions for whitening.

```
In [353]: def avg_of_rgb(original_img):
              u=np.array([0.0]*3)
              u=np.sum(original_img,axis=0)/len(original_img)
```

```
    return u

def sigma(original_img,u):
    sigma=np.array([0.0]*3)
    for i in range(len(original_img)):
        sigma=np.sum((original_img-u)**2,axis=0)
    sigma=sigma/len(original_img)
    return sigma

def whitening(original_img,u,sigma):

    whitening_img=np.array([0]*3)
    u=avg_of_rgb(original_img)

    sigma=sigma(original_img,u)

    whitening_img=(original_img-u)/sigma

    return whitening_img
```

0.0.3 Original image

In [372]:
```
img = cv2.imread('color3.jpg',1)
img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)


r,g,b =cv2. split(img)
r= r.flatten()
g= g.flatten()
b= b.flatten()

plt.subplot(1,1,1)
plt.imshow(img)
plt.title("Original Image")
plt.show()

# For comvenience about getting a clusterimage by K-means algorithms
img_10000=img.reshape(10000,3)
awe=img_10000.reshape(100,100,3)
```



0.0.4 Whitening of r,g,b values

In [355]:
```
whitening_img=whitening(img_10000,u,sigma)
u=avg_of_rgb(img_10000)
sigma=sigma(img_10000,u)
print(whitening_img)
```

```
[[-0.01238892 -0.01512736  0.00200521]
 [-0.02852177 -0.03482652 -0.0100728 ]
 [-0.03005823 -0.03670263 -0.0159105 ]
 ...
 [ 0.01603563  0.01442138  0.00764161]
 [ 0.01680386  0.01535944  0.00804421]
 [ 0.01219448  0.0097311   0.00562861]]
```

0.0.5 X,Y Coordinate and normalize a=1

In [373]:
```
rows=np.array([[0]*100]*100)
a=1

for j in range(100):
    for i in range(100):
        rows[j][i]=j
```

```
         columns=rows.T
         rows=rows.reshape(10000)
         #rows=normalize(rows)

         columns=columns.reshape(10000)
         #columns=normalize(columns)

         c = np.vstack([rows, columns])
         x_y_vector=c.T
         x_y_vector=x_y_vector/99
         print(x_y_vector)
```

```
[[0.         0.        ]
 [0.         0.01010101]
 [0.         0.02020202]
 ...
 [1.         0.97979798]
 [1.         0.98989899]
 [1.         1.        ]]
```

0.0.6 Concatenation x_y vector and r,g,b which is already whitened.

```
In [374]: add_all = np.hstack([x_y_vector, whitening_img])
          print(add_all)
```

```
[[ 0.          0.         -0.01238892 -0.01512736  0.00200521]
 [ 0.          0.01010101 -0.02852177 -0.03482652 -0.0100728 ]
 [ 0.          0.02020202 -0.03005823 -0.03670263 -0.0159105 ]
 ...
 [ 1.          0.97979798  0.01603563  0.01442138  0.00764161]
 [ 1.          0.98989899  0.01680386  0.01535944  0.00804421]
 [ 1.          1.          0.01219448  0.0097311   0.00562861]]
```

0.0.7 Functions

```
In [375]: def distance(add_all,init,k):
              d=np.zeros((k,10000))
              for i in range (k):
                  d[i]=np.sum((add_all-init[i])**2,axis=1)
              return d


          def kmeans_label(d,k):
              label=np.array([0]*10000)
              min_sum=np.min(d,axis=0)

              for j in range(len(d.T)):
```

```python
        for i in range(k):
            if d.T[j][i]==min_sum[j]:
                label[j]=i
    return label


def energy_func(img,avg_image,avg_label):
    ener_sum=0
    for i in range(10000):
        d=(img[i]-avg_image[avg_label[i]])**2
        ener_sum+=np.sum(d)

    return(ener_sum)/10000



def Kmeans_algorithm(label,init,add_all,d,k,list_ener):

    many=0
    kmeans_vec=np.array([[0.0]*5]*10000)
    label=kmeans_label(d,k)
    avg_label=np.array([0]*(len(add_all)))
    avg_image=np.array([[0.0]*5]*len(init))
    avg_label=np.copy(label)

    while(1):

        cnt=[0]*len(init)
        label=np.copy(avg_label)
        avg_label=np.array([0]*len(add_all))
        avg_image=np.array([[0.0]*5]*len(init))

        for k in range(len(label)):
            avg_image[label[k]]=avg_image[label[k]]+add_all[k]
            cnt[label[k]]+=1

        for l in range(len(init)):
            if (cnt[l]!=0):
                avg_image[l]=avg_image[l]/cnt[l]

        dis=distance(add_all,avg_image,len(init))
        avg_label=kmeans_label(dis,len(init))

        many+=1

        if(np.array_equal(label,avg_label)):
            break
```

```
            for i in range(len(label)):
                for j in range(len(init)):
                    if (avg_label[i]== j):
                        kmeans_vec[i]= avg_image[j]

            list_ener[many-1]= energy_func(add_all,avg_image,avg_label)

        print("Iteration Number:",many)



        return kmeans_vec
```

0.0.8 De_whitening R,G,B value.

```
In [379]: def dewhitening(kmeans_color,u,sigma):

              de_whitening_img=np.array([0]*3)


              de_whitening_img=sigma*kmeans_color+u

              return de_whitening_img
```

0.0.9 k=10

```
In [424]: a=1
          k=10
          init=np.random.random((k,5))
          d=distance(add_all,init,k)
          label=kmeans_label(d,k)
          list_ener10=np.array([0.0]*1000)
          kmeans_vec_10=Kmeans_algorithm(label,init,add_all,d,k,list_ener10)

          #Cut for kmeans to kmeans_rgb
          kmeans_color10=np.array(kmeans_vec_10[:,2:5])
          de_whitening_img10=dewhitening(kmeans_color10,u,sigma)
          de_whitening_img10=de_whitening_img10.reshape(100,100,3)
          de_whitening_img10=de_whitening_img10.astype(np.int64)
```

```
Iteration Number: 67
```

0.0.10 k=30

```
In [382]: a=1
          k=30
```

```
init=np.random.random((k,5))
d=distance(add_all,init,k)
label=kmeans_label(d,k)
list_ener30=np.array([0.0]*1000)
kmeans_vec_30=Kmeans_algorithm(label,init,add_all,d,k,list_ener30)

#Cut for kmeans to kmeans_rgb
kmeans_color30=np.array(kmeans_vec_30[:,2:5])
de_whitening_img30=dewhitening(kmeans_color30,u,sigma)
de_whitening_img30=de_whitening_img30.reshape(100,100,3)
de_whitening_img30=de_whitening_img30.astype(np.int64)
```

```
Iteration Number: 190
```

0.0.11 k=50

In [384]:
```
a=1
k=50
init=np.random.random((k,5))
d=distance(add_all,init,k)
label=kmeans_label(d,k)
list_ener50=np.array([0.0]*1000)
kmeans_vec_50=Kmeans_algorithm(label,init,add_all,d,k,list_ener50)

#Cut for kmeans to kmeans_rgb
kmeans_color50=np.array(kmeans_vec_50[:,2:5])
de_whitening_img50=dewhitening(kmeans_color50,u,sigma)
de_whitening_img50=de_whitening_img50.reshape(100,100,3)
de_whitening_img50=de_whitening_img50.astype(np.int64)
```

```
Iteration Number: 282
```

0.0.12 k=60

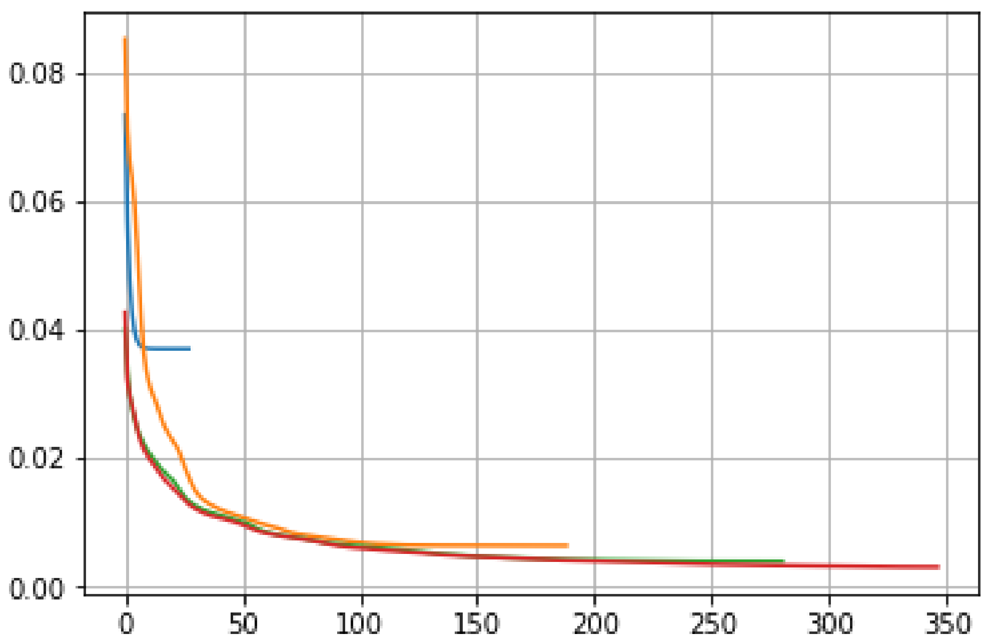
In [401]:
```
a=1
k=60
init=np.random.random((k,5))
d=distance(add_all,init,k)
label=kmeans_label(d,k)
list_ener60=np.array([0.0]*1000)
kmeans_vec_60=Kmeans_algorithm(label,init,add_all,d,k,list_ener60)

#Cut for kmeans to kmeans_rgb
kmeans_color60=np.array(kmeans_vec_60[:,2:5])
de_whitening_img60=dewhitening(kmeans_color60,u,sigma)
de_whitening_img60=de_whitening_img60.reshape(100,100,3)
de_whitening_img60=de_whitening_img60.astype(np.int64)
```

```
Iteration Number: 348
```

0.1 Visualize the energy curve for both the intensity energy and the spatial energy for each K.

In [420]:
```
y1=np.copy(list_ener10[:28])
y2=np.copy(list_ener30[:189])
y3=np.copy(list_ener50[:281])
y4=np.copy(list_ener70[:347])
plt.grid()
plt.plot(y1)
plt.plot(y2)
plt.plot(y3)
plt.plot(y4)
plt.plot()
```

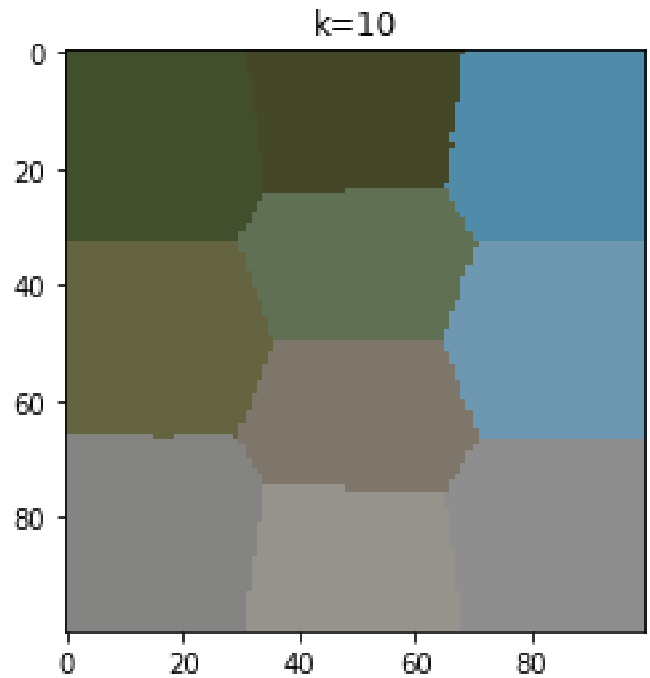
Out[420]: []



0.2 Visualize the clustering results with varying k and a using the centroid color m_k for each cluster k.

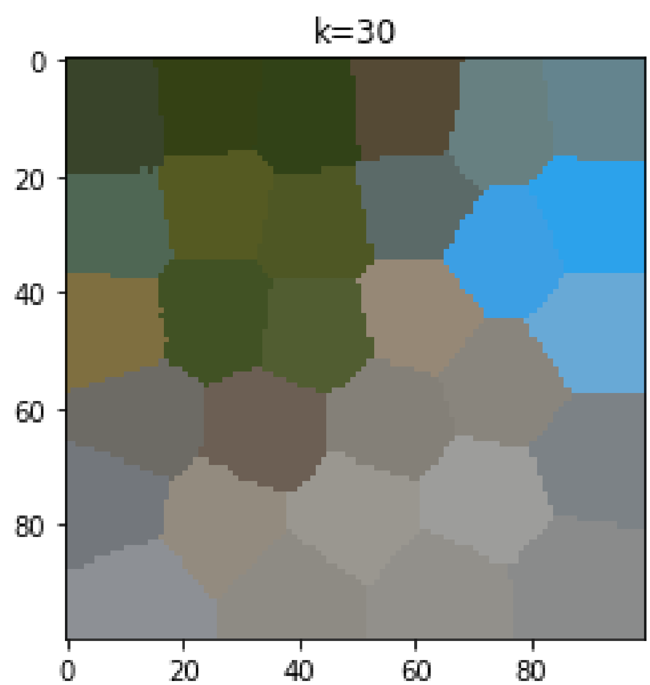
0.2.1 When k=10

In [425]:
```
plt.imshow(de_whitening_img10)
plt.title("k=10")
plt.show()
```



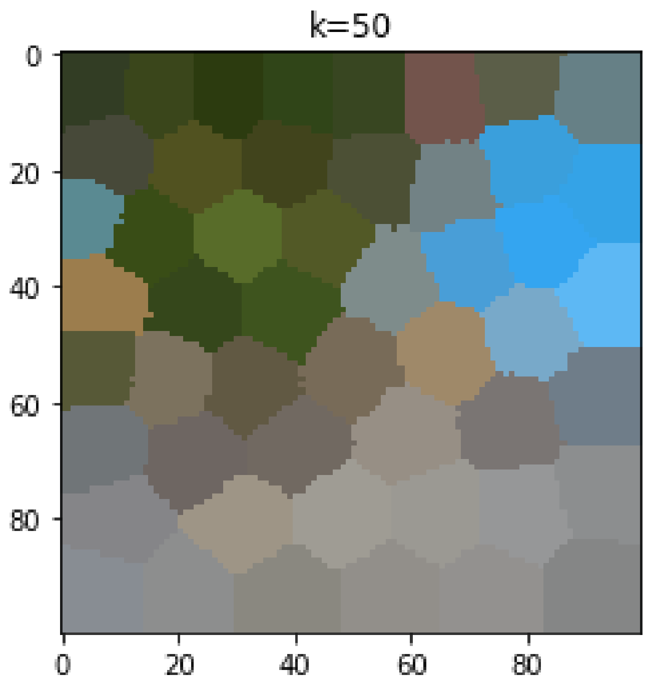
0.2.2 When k=30

```
In [426]: plt.imshow(de_whitening_img30)
          plt.title("k=30")
          plt.show()
```



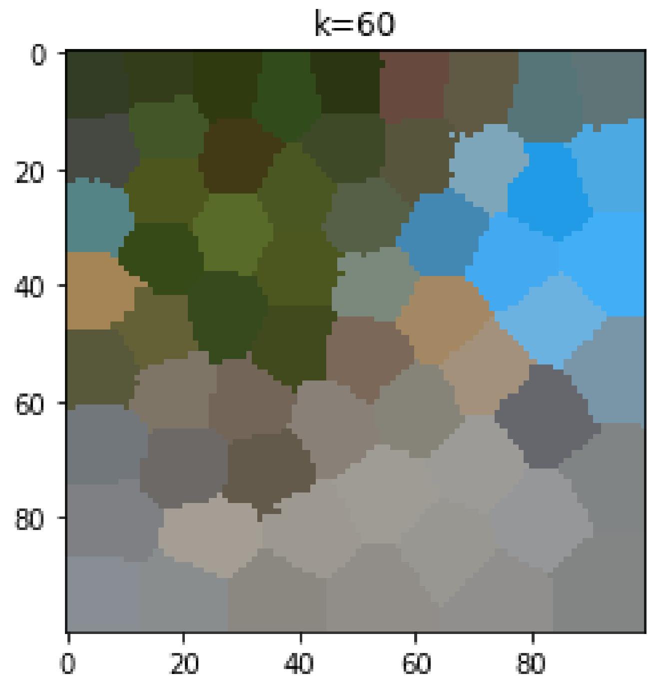
0.2.3 When k=50

In [427]:
```
plt.imshow(de_whitening_img50)
plt.title("k=50")
plt.show()
```



0.2.4 When k=60

In [428]:
```
plt.imshow(de_whitening_img60)
plt.title("k=60")
plt.show()
```



0.2.5 Original Image.

```
In [422]: plt.imshow(img)
          plt.title("Original Image")
          plt.show()
```