Assignmet 2 – Image Compression by K-Means

Introduction

Clustering is an unsupervised learning technique that gives just the data (without target labels) to find patterns of the data. In this experiment, it is going to be used K-Means method, that finds optimum centroid points to clustered data, for 5 different images as seen in “Figure-1a,1b,1c,1d and 1e”

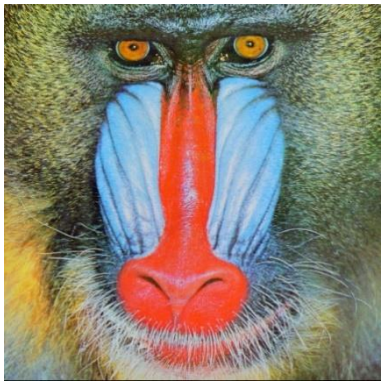


Figure 1a – Baboon Image

Figure 1b – Landscape Image

Figure 1c – Lenna Image

Figure 1d – Umbrella Image

Figure 1e – Peppers Image

Experiment Setup

Aim of this experiment, analyzing 5 different images to compress by using K-Means and finding the optimum clustered images in terms of image size and color quality. Since images ‘raw data shapes are (512 x 512 x 3) respectively width, height, and color channels, it should be resized to get better performance. Therefore, images are resized to (256,256,3). Although

images size approximately decreased 4 times, images' quality did not change significantly (as show in "Figure-2a,2b,2c,2d and 2e")

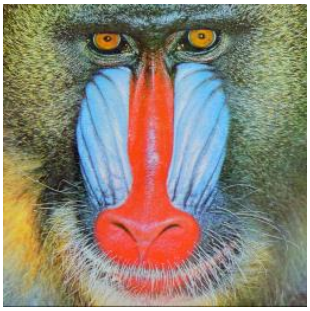


Figure 2a – Baboon Image
Size: 256 x 256

Figure 2b – Landscape Image
Size: 256 x 256

Figure 2c – Lenna Image
Size: 256 x 256

Figure 2d – Umbrella Image
Size: 256 x 256

Figure 2e – Peppers Image
Size: 256 x 256

	Baboon	Landscape	Lenna	Umbrella	Peppers
Image size in KB (512 x 512)	617.941	315.895	468.533	409.736	504.837
Number of unique colors (512 x 512)	230,427	58,964	148,279	135,560	183,525
Image size in KB (256 x 256)	152.558	93.681	116.361	116.844	115.228
Number of unique colors (256 x 256)	62,070	34,973	48,331	45,085	54,108

Table 3 – Image size (number of bytes) and number of unique colors in two different size

In addition, it can be observed in "Figure-3" that there is a positive relationship between unique colors and the number of bytes, and it can be easily seen that which specific image contains a lot of bytes and unique colors this fact is going to be used to decide optimum K later. Besides, to compress images efficiently, it should be reshaped as a 2-d array, which means height x width as one dimension and color channels another one, so the results of images are (65536,3). Also, cluster centers of the pixel values of the image (K) should be chosen with the power of 2. Since images size are 256 x 256, maximum range should be 2^8.

Implementation Details

As it mentioned above, K number should be used increased from 2 to 256 to be the power of 2. K value tells number of different colors in a single image. Therefore, it should be compressed by using 8 different numbers of cluster centers in each image type. (seen in "Figure-4,5,6,7 and 8")

Baboon Images

Figure 4a – K = 2^1

Figure 4b – K = 2^2

Figure 4c – K = 2^3

Figure 4d – K = 2^4

Figure 4e – K = 2^5

Figure 4f – K = 2^6

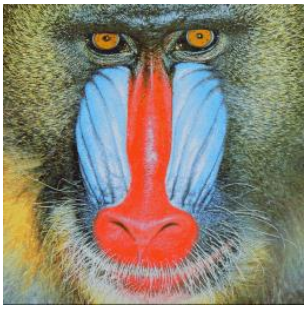


Figure 4g – K = 2^7

Figure 4h – K = 2^8

Landscape Images

Figure 5a – K = 2^1

Figure 5b – K = 2^2

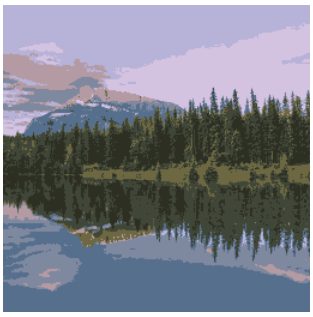


Figure 5c – K = 2^3

Figure 5d – K = 2^4

Figure 5e – K = 2^5

Figure 5f – K = 2^6

Figure 5g – K = 2^7

Figure 5h – K = 2^8

Lenna Images

Figure 6a – K = 2^1

Figure 6b – K = 2^2

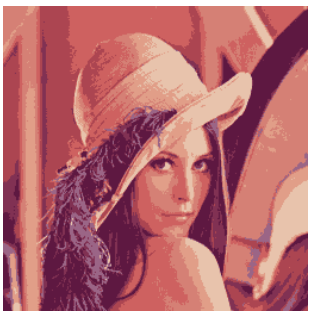


Figure 6c – K = 2^3

Figure 6d – K = 2^4

Figure 6e – K = 2^5

Figure 6f – K = 2^6

Figure 6g – K = 2^7

Figure 6h – K = 2^8

Peppers Image

Figure 7a – K = 2^1

Figure 7b – K = 2^2

Figure 7c – K = 2^3

Figure 7d – K = 2^4

Figure 7e – K = 2^5

Figure 7f – K =2^6

Figure 7g – K = 2^7

Figure 7h – K = 2^8

Umbrella Images

Figure 8a – K = 2^1

Figure 8b – K = 2^2

Figure 8c – K = 2^3

Figure 8d – K = 2^4

Figure 8e – K = 2^5

Figure 8f – K = 2^6

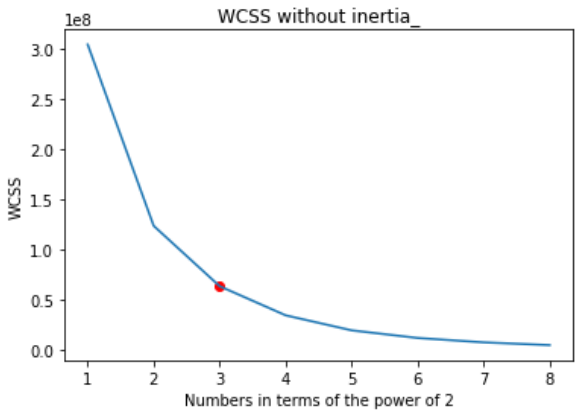
Figure 8g – K = 2^7

Figure 8h – K = 2^8

Results

After creating 8 different compressed images in each image type, it should be calculated 3 different metrics, which are WCSS (Within Cluster Sum of Squares), BCSS (Between Cluster Sum of Squares), Explained Variance (Silhouette Coefficients), in order to find optimum number of K. Also, there is another method that decides the K value is the elbow point method. The method idea is finding the shape of the graph of the sum of squared errors, which looks like a human's arm, and in this graph, most similar to elbow point is the optimum K value. As seen in "Figure-9,10,11,12 and 13" all 5 images show one elbow point

which is $2^3 = 8$ whether they calculated pre-written attribute(inertia_) by “sklearn liblary” or not.



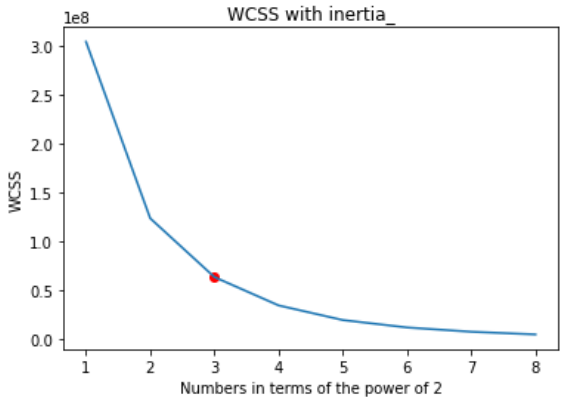
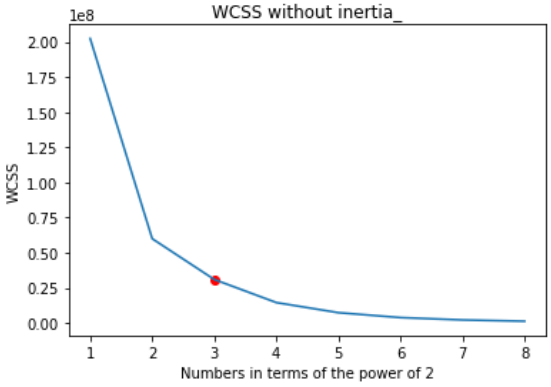


Figure 9 – WCSS/SSE vs K value for Baboon Images



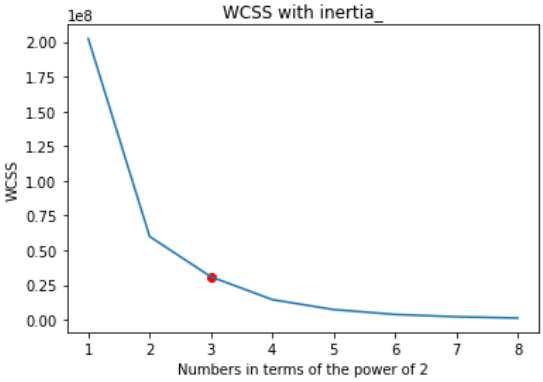
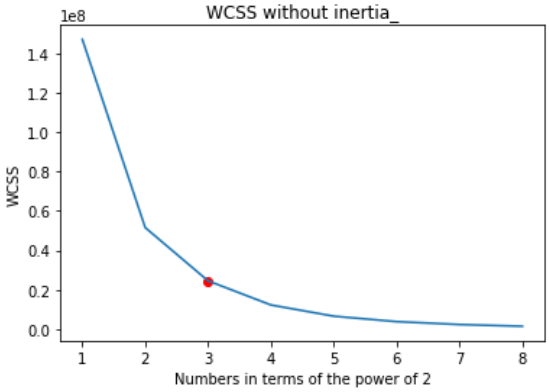


Figure 10 – WCSS/SSE vs K value for Landscape Images



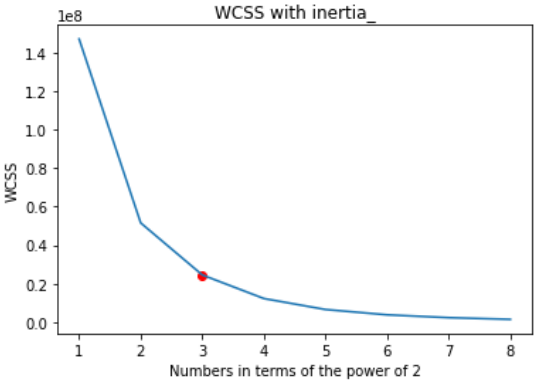
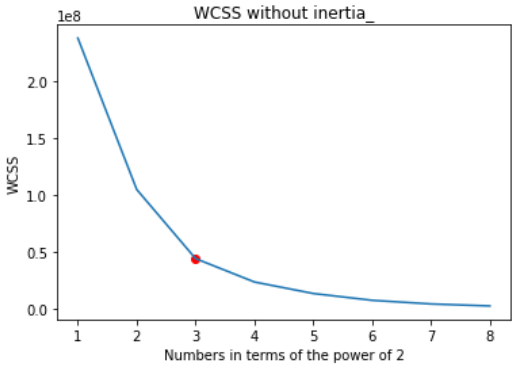


Figure 11 – WCSS/SSE vs K value for Lenna Images



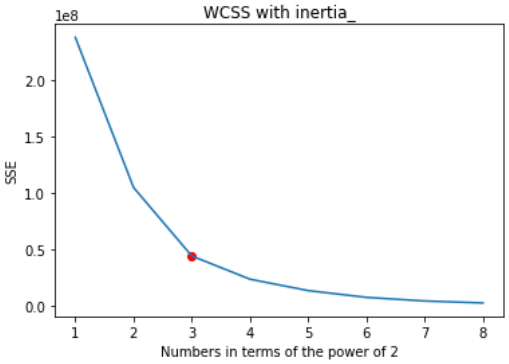
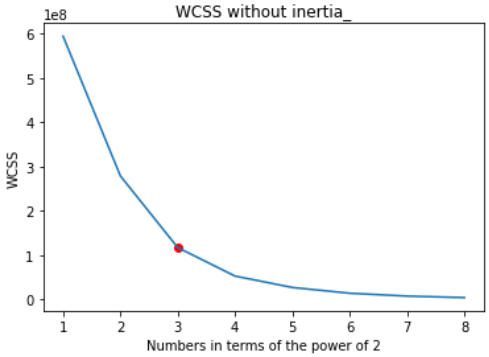


Figure 12 – WCSS/ SSE vs K value for Peppers Images



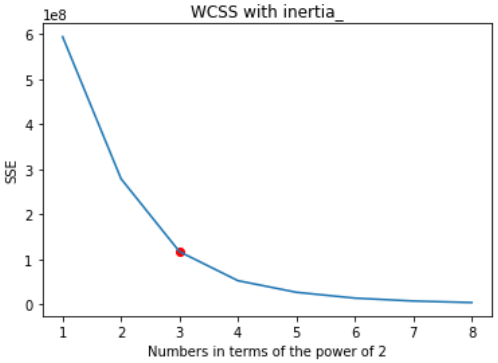


Figure 13 – WCCS/SSE vs K value for Umbrella Images

	K = 2^1	**K = 2^2**	**K = 2^3**	**K = 2^4**	**K = 2^5**	**K = 2^6**	**K = 2^7**	**K = 2^8**
WCSS	3.04E+08	1.23E+08	6.33E+07	3.43E+07	1.94E+07	1.182E+07	7.45E+06	4.72E+06
BCSS	2.30E+08	4.11E+08	4.71E+08	5.00E+08	5.16E+08	5.22E+08	5.27E+08	5.30E+08
Explained Variance	43.12%	76.90%	88.15%	93.58%	96.37%	97.79%	98.61%	99.12%
Image Size	10.54 KB	16.43 KB	28.74 KB	45.33 KB	68.22 KB	96.42 KB	120.59 KB	136.89 KB
Unique colors	2	4	8	16	32	64	128	256
Name of the colors	Dim gray, dark gray	Dark olive green, gray, lightsteel blue, tomato	Dark slate gray,dim gray, slategray,dim gray, sky blue, dark gray, dark khaki, tomato	Dark slate gray, dark olive green, dim gray, cadet blue,gray,sky blue, sienna,peru, chocolate	Silver,rosy brown, orangered, tomota, indian red, dark khaki, peru, Dark gray, Dark golden rod,sky blue	Black, gray,dim gray, sky blue, olive drab, dark khaki, dark golden rod, pale violet red,light steel blue, dark sea green	Black, dark slate gray, corn flower blue, sienna, dark khaki, peru,tomato, light coral, silver, cadet blue	Dim gray, black, gray, steel blue, slate gray,indian red, peru, orangered, saddle brown,silver

*Table 14 – Several metrics related to **baboon images.***

As shown in “Figure-14” it can be chosen optimum K value with these statistics. It is mentioned earlier, elbow point is 2^3 for baboon images but it can be observed both original image (“Figure-2”) and compressed images(“Figure-4”) k value should be 2^5 because before the 2^5 baboon’s eyes are different. Also explained variance value (96.37%) is quite satisfied.Besides, it takes up more than half of the orginal image size, which is 152.558 KB (“Figure-3”) . Moreover, it can be used only 32 different colors comparing to original number of colors in image ,which is 62,070.

	K = 2^1	**K = 2^2**	**K = 2^3**	**K = 2^4**	**K = 2^5**	**K = 2^6**	**K = 2^7**	**K = 2^8**
WCSS	2.02E+08	6.00E+07	3.10E+07	1.46E+07	7.40E+06	3.90E+06	2.23E+06	1.32E+06
BCSS	5.28E+08	6.71E+08	7.00E+08	7.17E+08	7.24E+08	7.27E+08	7.29E+08	7.30E+08
Explained Variance	72.31%	91.79%	95.76%	98.00%	98.99%	99.47%	99.70%	99.82%
Image Size	2.99 KB	6.58 KB	15.33 KB	21.65 KB	33.34 KB	46.17 KB	59.93 KB	71.51 KB
Unique colors	2	4	8	16	32	64	128	256
Name of the colors	Dim slate gray, silver	Dark slate gray, slate gray, light slate gray, thistle	Dark slate gray, slate gray, dark olive green light slate gray, dark gray, light steel blue, thistle	Black, dark slate gray, steel blue, dim gray, dark olive green , dark salmon, gray, thistle	Black, gray, indian red, dim gray, steel blue, dark salmon, silver,thistle, olive drab,slate gray	Black,dark slate gray, gray, steel blue, silver, thistle, burly wood, dark olive green, silver, peru,sienna	Black, dark slate gray, gray, dim gray, olive drab,pink, thistle, dark salmon, gains boro, rosy brown	Dim gray, dark gray, silver, rosy brown, peru,silver,pink burly wood, light salmon,thistle

*Table 15 – Several metrics related to **landscape images.***

As shown in “Figure-15” it can be chosen optimum K value with these statistics. Even though the elbow point is 2^3 , it should be chosen 2^6 . Also, explained variance values are quite high before the K = 2^6 but looking at compressed images (“Figure-5”) it can be understood that there are very similar colors, especially in sea and sky. In order to distinguish the K value should be 2^6 . Moreover, image size takes up half of the original image size.

As illustrated in “Figure-16” it can be chosen optimum K value based on these statistics. The elbow point regarding this image is 2^3 and explained variance is 93.98%, means 93.98 % of this image fits the original image, so that K value should be 2^3. Also looking at the compressed images (“Figure-6”) K = 2^3 can be easily satisfying in terms of distinguishing colors or analyzing her face so forth. Moreover, it takes up a very small amount of place compared to the original image size which is 116.361 KB (“Figure-3”)

	$K = 2^1$	$K = 2^2$	$K = 2^3$	$K = 2^4$	$K = 2^5$	$K = 2^6$	$K = 2^7$	$K = 2^8$
WCSS	1.47E+08	5.15E+07	2.45E+07	1.23E+07	6.60E+06	3.85E+06	2.38E+06	1.50E+06
BCSS	2.60E+08	3.56E+08	3.83E+08	3.94E+08	4.00E+08	4.03E+08	4.05E+08	4.06E+08
Explained Variance	63.92%	87.36%	93.98%	96.98%	98.38%	99.05%	99.42%	99.63%
Image Size	5.29 KB	11.09 KB	19.14 KB	29.00 KB	44.90 KB	62.82 KB	81.80 KB	96.67 KB
Unique colors	2	4	8	16	32	64	128	256
Name of the colors	Brown, dark salmon	Brown, indian red, light coral, burly wood	Indigo, brown, gary, sienna, indian red, light coral, dark salmon, wheat	Indigo,brown, dim gray, gray, indian red, sienna, rosy brown, tan, wheat,burly wood	Indigo,brown,purple, sienna, tan, maroon, gray, dark salmon, navajo white, rosy brown	Indigo, indian red, tan, silver,light coral, gray, sienna, wheat, navajo white, brown	Light pink, sienna, tan, silver, bisque, wheat, gray, indigo, brown, peach puff	Midnight blue, indigo, maroon, purple, brown, dim gray, dark salmon, tan, silver, light coral, wheat

*Table 16 – Several metrics related to **lenna images.***

	$K = 2^1$	$K = 2^2$	$K = 2^3$	$K = 2^4$	$K = 2^5$	$K = 2^6$	$K = 2^7$	$K = 2^8$
WCSS	2.38E+08	1.05E+08	4.44E+07	2.38E+07	1.37E+07	7.73E+06	4.53E+06	2.79E+06
BCSS	3.77E+08	5.11E+08	5.71E+08	5.91E+08	6.02E+08	6.08E+08	6.11E+08	6.13E+08
Explained Variance	61.35%	82.95%	92.80%	96.13%	97.77%	98.74%	99.26%	99.55%
Image Size	4.52 KB	9.51 KB	16.41 KB	27.09 KB	39.40 KB	54.15 KB	70.77 KB	88.36 KB
Unique colors	2	4	8	16	32	64	128	256
Name of the colors	Brown, dark khaki	Maroon, olive drab, dark khaki, fire brick	Black, dark olive green, olive drab, yellow green, brown, dark khaki, silver, fire brick	Black, marron, saddle brown, olive drab, dark red, silver, indian red, rosy brown, dark sea green, dark khaki, fire brick	Black, maroon, silver, tan, indian red, peru, fire brick, brown, gray, yellow green	Chocolate, indian red, dark salmon, tan, fire brick, peru, silver, sienna, dark red, maroon	Black, maroon, dim gray, gray, brown, dark red, peru, sienna, saddle brown, silver	Crimson, indian red, tan, silver, brown, purple, dark sea green, yellow green, gray, fire brick

*Table 17 – Several metrics related to **peppers images.***

As illustrated in "Figure-17" it can be chosen as optimum K value by using these statistics. The elbow point of this image is 2^3 and explained variance of 2^3 is 92.80% so that K value should be 2^3. Besides, looking at the compressed images ("Figure-7"), "Figure-7c" can be

easily used for detection of peppers and it is very efficient in terms of image size, which is one-seventh of original image size.

	K = 2^1	**K = 2^2**	**K = 2^3**	**K = 2^4**	**K = 2^5**	**K = 2^6**	**K = 2^7**	**K = 2^8**
WCSS	5.95E+08	2.79E+08	1.17E+08	5.27E+07	2.69E+07	1.40E+07	7.53E+06	4.15E+06
BCSS	6.07E+08	9.23E+08	1.09E+09	1.15E+09	1.17E+09	1.187E+09	1.19E+09	1.20E+09
Explained Variance	50.52%	76.79%	90.26%	95.61%	97.76%	98.83%	99.37%	99.65%
Image Size	5.00 KB	9.57 KB	15.32 KB	25.78 KB	35.63 KB	50.61 KB	63.72 KB	76.14 KB
Unique colors	2	4	8	16	32	64	128	256
Name of the colors	Brown, tan	Dark slate gray, silver, peru, red	Black, purple , dim gray, fir e brick, light gray, tan , re d, orange	Black, indigo, cadet blue, dark olive green, purple, indian red, dark red, red, gold, light pink	Black, cadet blue, dark salte gray, indigo, purple, tan, gold, orange, fire brick, gray	Black, midnight blue, indigo, tan, red, orange, linen, dark orange, red, pink	Black, indigo, gray, peru, wheat, tan, khaki, bisque, red, beige	Tan, silver, red, tomato, golden rod, crimson, khaki, gold, pink, lavender

*Table 18 – Several metrics related to **umbrella images.***

As illustrated in “Figure-18” it can be chosen as optimum K value with these statistics. The elbow point of this image is same as others which is 2^3 and explained variance of this K value is 90.26% means that this image has a 90% success rate compared to the original image. Therefore, optimum K value should be 2^3 because looking at the compressed images (“Figure-8”) it can be easily distinguished umbrella in third one and it can clearly be used in image detection so forth. It takes up one-eighth compared to the original image size that is another reason to choose this K value.

Conclusion

Consequently, this experiment shows that K-Means method is a very effective to compress images. Besides, by using this method, it can be gotten sufficient quality with less image size. Also, the output images of this experiment can be used for more comprehensive topics such as computer vision so forth.