Vector Quantization: Cross Comparison of RGB and Gray-scale Images

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Introduction

In this analysis of the K Means algorithms, we perform vector quantization on images. More specifically, we analyse the results of vector quantization on the same image twice. In the first iteration, the image is in the Red-Green-Blue (RGB) color model. In the second iteration, the image is in gray-scale. RGB is the typical color model that we view images. Gray-scale is the average of the RGB values. We also examine luminosity's effects on vector quantization. Luminosity is the intrinsic brightness of an image. Vector quantization is the process of reducing the amount of attributes of an image in order to compress the image without ruining the likeness and integrity of the image. The goal of this examination is to discover if the different color models can share the same k values when performing vector quantization. Additionally, we investigate if the loss of luminosity weakens the performance of the algorithm on gray-scale images.

Methodology

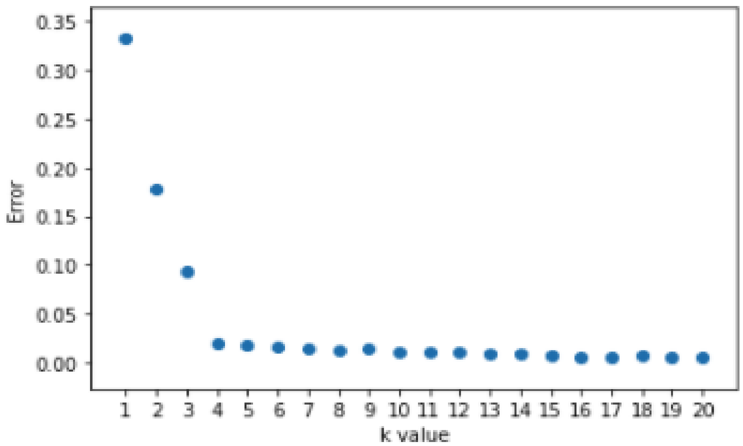
We utilize the KMeans() from the sklearn toolkit. K Means is an algorithm which identifies the mean of each cluster in the data. The algorithm begins by selecting random points as centers. Every point is assigned to the center that is closest to it. Then the centers move to the average of the points that are assigned to it. This process continues until the centers stop moving. When performing K Means, we must identify the number of clusters. There are two methods to achieve this. The first method is to display a scatter plot and visually identify the number of clusters, and this number will be K. This can be a useful method when given two dimensional data, but this method would not work for a higher dimensional data set because it is impossible to visualize and interpret data in that form.Therefore, we typically use a second method.

In this method, we run the K Means algorithm multiple times and record the error in each iteration. The error term is calculated by taking the sum of the square root of the distance from each point to the center that is closest to it. The error metric is represented by

$E = \sum(X_i - C_j)^2$, where X_i are the training points and C_j is the closest center to X_i.

In this analysis, we run the K Means algorithm 20 times, spanning k from 1 to 20. After each error metric is recorded, we plot the k value and its corresponding error metric.

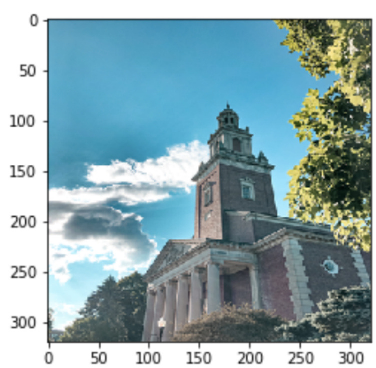
We read in the image using the Pillow module and output two arrays: the original RGB image array , and the grey scale image array. After we contain the array of the images, we implement the process of finding the optimum k as described above. Once we compare their optimum k, we fit the K Means algorithm to each image and output the new compressed images. Thus, our final output is two images that we are recreated using vector quantization. Below is an example output of the elbow graph.



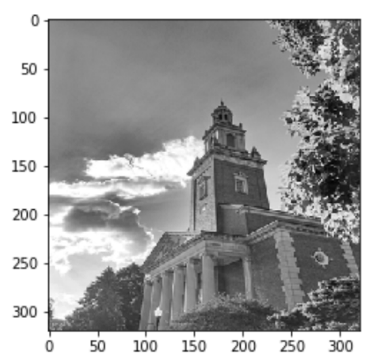
As we can see above, the error metric decreases exponentially as k increases. The "elbow" of the graph is where we identify the number of centers. Looking at this graph, it seems that K is equal to 4.

Analysis across Color Scales

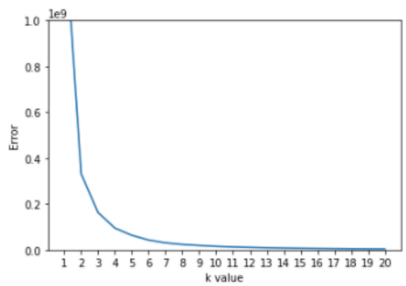
The image that we choose to use is Swasey Chapel at Denison University. Additionally, it should be noted that each photo is the same size of 320x320 pixels. Below are two sets of images. The first row is the original images. The second row is the results of finding the optimum K. The left image is the original image in RGB scale, and the right image is the same exact image except in the gray-scale.



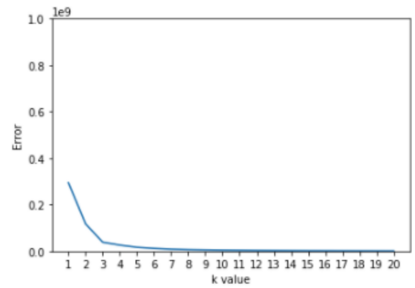
(a) Swasey Chapel in RGB color model



(b) Swasey Chapel in gray-scale

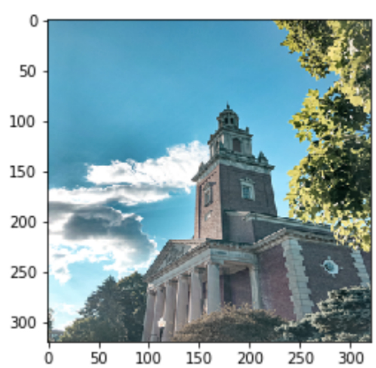


(c) Swasey Chapel in RGB color model

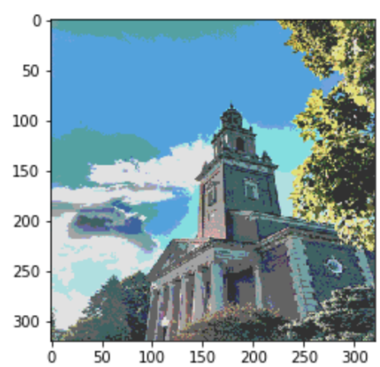


(d) Swasey Chapel in gray-scale

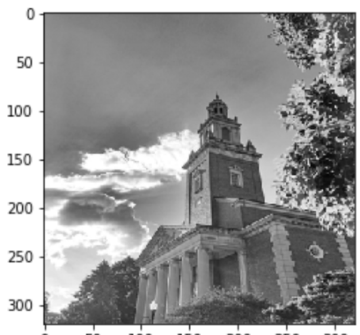
As we can see graphs above, the RGB photo should have a K value of 4 meanwhile the gray-scale image has a K value of 3. This result suggests two insights. The first insight is the K Means algorithm should be implemented on the images with a K value of 4 and 3, respectively. This suggest that there are four clusters present in the RGB image and three clusters present in the gray-scale image. The second insight found is (in this instance) the image in RGB has a very similar amount of clusters as the image in gray-scale. Another interesting note is that the gray-scale image has significantly less error than the RGB model. Therefore, we run the K Means algorithm on each image with a K value of 4 and 3 and reconstruct the image using the compressed image array. Below are the results. The left column is the original images, and the right column is the reconstructed images.



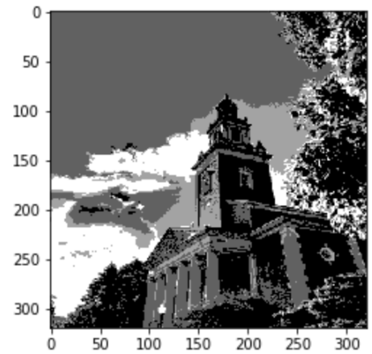
(e) Original Swasey Chapel (RGB)



(f) Reconstructed Swasey Chapel (RGB)



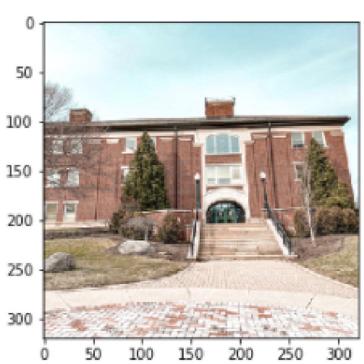
(g) Original Swasey Chapel (gray-scale)



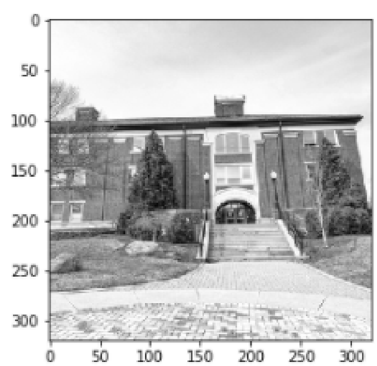
(h) Reconstructed Swasey Chapel (gray-scale)

We can be confident that the K Means algorithm is running properly given these results. Each image is reconstructed almost perfectly and given more clusters, it could be made sharper. It is clear that the 4 was a satisfactory K value for this dataset. This suggests that the prior idea of RGB and gray-scale images having the same amount of clusters is more likely.

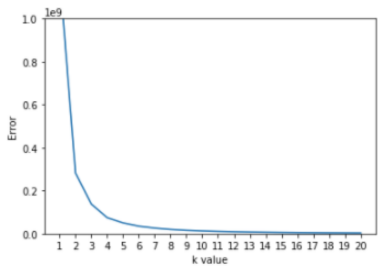
We did further tests with academic buildings at Denison University. Olin Science Hall also returned very impressive results as well. Thus, we can be confident that the same image in RGB and gray-scale will have the same number of clusters. Below are the original images and elbow graphs of Olin Science Hall in RGB and gray-scale.



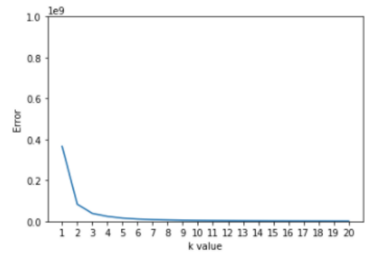
(i) Olin Hall (RGB)



(j) Olin Hall (gray-scale)

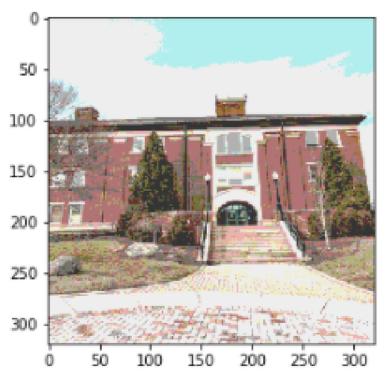


(k) Olin Hall Elbow Graph (RGB)

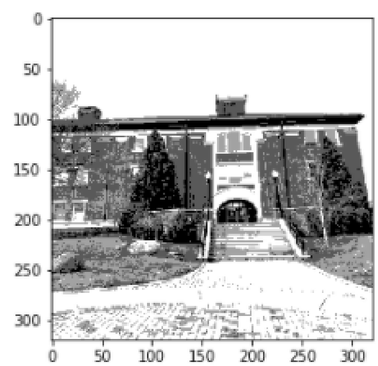


(l) Olin Hall Elbow Graph (gray-scale)

Here we see that the K values are the exact same. The K value is three for each image. Again, the overall error of the gray-scale image appears to be far less than the RGB image. These graphs suggests that the color model has no significant effect on the clustering algorithm. Below are the reconstructed images. We can see in these images below that the results are very impressive.



(m) Reconstructed Olin Hall (RGB)



(n) Reconstructed Olin Hall (gray-scale)

Further Exploration on Gray-scale

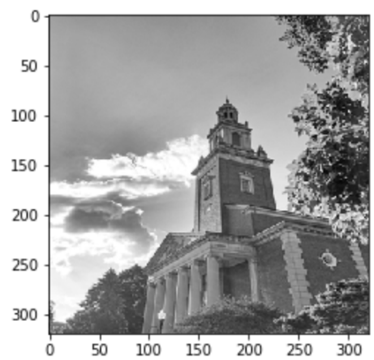
As mentioned earlier, converting RGB to gray-scale is a very simple equation. Gray-scale can be equated as

$$(R + G + B)/3.$$

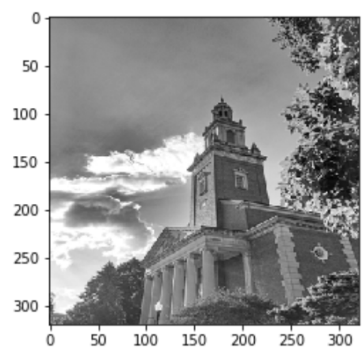
Gray-scale is the average of the three colors. The luminosity of images does not translate as nicely. Luminosity is the intrinsic brightness of an image. Therefore, it is difficult to accurately convert brightness of colors into a grey image. However, there are a couple of facts that have helped researchers find a solution to this problem. They find that red colors have the most wavelength of the three colors meanwhile green colors tend to have a soothing effect on the eyes. Therefore, we need to weight the colors to reflect the luminosity in the original image by decreasing the effect of red and increasing the effect of green. The universal equation to convert RGB to grey-scale is

$$(.3 * R) + (.59 * G) + (.11 * B).$$

The function uses this equation to convert the original image into a gray-scale image. We test the effects of using the equation that has no weight on the luminosity on the equation. Below are the images. The left is Swasey Chapel with luminosity and the right is Swasey Chapel without the calculated luminosity.

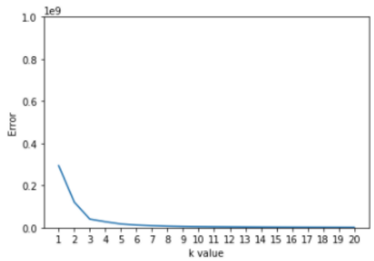


(o) Swasey Chapel with luminosity

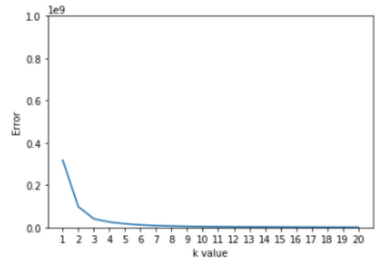


(p) Swasey Chapel without luminosity

The differences are very subtle, but it is clear that the image with luminosity is brighter than the image without luminosity. We then determine which K value will be appropriate and check if they are different. Below are the graphs where we identify the best K.

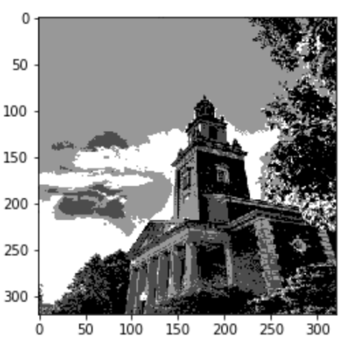


(q) Swasey Chapel with luminosity

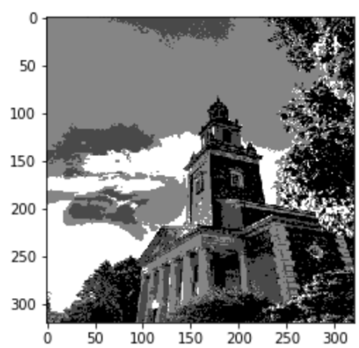


(r) Swasey Chapel without luminosity

As we can see, they are still extremely similar and the number of clusters appear to be 3. Therefore, we are more confident that the luminosity appear to has no affect on the number clusters. So when we reconstruct the images, they will look very similar. The results are below.



(s) Swasey Chapel with luminosity



(t) Swasey Chapel without luminosity

The images are virtually the same. Again, this suggests that the luminosity is not a determinant in a K Means analysis.

Conclusion

This examination tests the vector quantization method on images through two experiments. The first experiment analyses an image in two different color schemes: RGB and gray-scale. Using the image of Swasey Chapel, it appears that the K Means algorithm finds the same number of clusters in the RGB image and the gray-scale image. This suggests that during the conversion process, the distinguishing features of the image are maintained. The second experiment analyses if luminosity impacts the performance of vector quantization on gray-scale images. In this experiment, we create two grey-scale images: one with luminosity and one without luminosity. Using the ”elbow” technique, we find the number of clusters to be the same despite the difference in luminosity. Similar to the first experiments, this attribute of images has no affect on the distinguishing features on images. Although both of the experiments provided no intriguing results, we can still find value in recognizing the vector quantization and the K Means algorithm are powerful tools that can expand across color models, and many image attributes, such as luminosity.