## K-Means Clustering Report

## Algorithm Design

### Clustering

The algorithm implemented used for clustering, clusters each channel separately as the values in one channel doesn’t depend on the values of other channel. This also allows a simpler way to calculate the points that belong to a certain cluster as the distances are one dimensional and the boundary between 2 clusters is simply a scalar value that can be compared against each point. This approach also allows us to parallelize the clustering task as each channel can be clustered independently.

It should be noted however that since each channel can be clustered independently and since each channel would have clusters. The total number of clusters for a given would be for any image and the total unique color combinations addressable through these clusters would be: , since the mean value in one channel can combine with any of the number of means from each of the other 2 channels. Thus, the number of unique colors stored for each value of are:

|  |  |
| --- | --- |
|  | Number of unique colors |
| 2 | 8 |
| 3 | 27 |
| 10 | 1000 |
| 20 | 8000 |
| 40 | 64000 |

### Stopping

The stopping criteria initially used assumed that the mean squared error would decrease monotonically as the number of iterations increases. However, it was observed that this was not the case, and the MSE could increase or decrease between subsequent iterations. Thus, the final stopping criteria used resembled that of early stopping, where if after number of iterations the error didn’t decrease, the algorithm stopped.

### Initialization Strategy

The initialization strategy used for the non-random case, first obtained the minimum and maximum values for each channel. It then simply chose the means such that the distance between them would be equal, and within the bounds of the minimum and maximum values.

## Results

The following is the first sample image on which clustering was performed:

A group of men sitting on a car

Description automatically generated

The following table shows the resulting image for each value of , along with their mean squared error and the number of iterations until convergence.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Initialization Strategy | Iterations | MSE | Image |
| 2 | Random | 4 | 23.932 |  |
| 2 | Random | 5 | 23.935 |  |
| 2 | Equidistant | 4 | 23.935 |  |
| 3 | Random | 4 | 15.93 |  |
| 3 | Random | 8 | 16.05 |  |
| 3 | Equidistant | 9 | 15.985 |  |
| 10 | Random | 2 | 6.35 |  |
| 10 | Random | 5 | 6.069 |  |
| 10 | Equidistant | 24 | 4.694 |  |
| 20 | Random | 1 | 5.367 |  |
| 20 | Random | 1 | 4.705 |  |
| 20 | Equidistant | 11 | 2.583 |  |
| 40 | Random | 1 | 2.337 |  |
| 40 | Random | 1 | 2.226 |  |
| 40 | Equidistant | 11 | 1.4 |  |

The following image was used as the second reference image:

A group of men standing on a road

Description automatically generated

While table below shows the results from clustering:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Initialization Strategy | Iterations | MSE | Image |
| 2 | Random | 11 | 44.684 |  |
| 2 | Random | 11 | 44.671 |  |
| 2 | Equidistant | 6 | 44.671 |  |
| 3 | Random | 4 | 31.227 |  |
| 3 | Random | 9 | 29.452 |  |
| 3 | Equidistant | 9 | 29.296 |  |
| 10 | Random | 1 | 19.339 |  |
| 10 | Random | 1 | 23.447 |  |
| 10 | Equidistant | 26 | 8.9449 |  |
| 20 | Random | 1 | 7.907 |  |
| 20 | Random | 1 | 10.903 |  |
| 20 | Equidistant | 14 | 4.475 |  |
| 40 | Random | 1 | 3.538 |  |
| 40 | Random | 164 | 4.845 |  |
| 40 | Equidistant | 2 | 2.34 |  |

Q. Which initialization strategy led to better clustering.

Based on the results above although visually random initialization would yield similar results to that of equidistant initialization, based on MSE. The equidistant initialization almost always did better or at worse as good as random initialization.

Q. Does always a smaller MSE correspond to a more pleasing visual reconstruction?

We can observe that as increases, MSE consistently decreases for the 2 images and the reconstruction consistently improves. Thus, a lower MSE does lead to a better reconstruction of the original image.

A noteworthy observation is that for , the reconstructed image is almost indistinguishable from the original.