KMeans Clustering
MNIST digits Dataset

Report By
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Objective:

In this project we apply KMeans clustering algorithm to cluster the MNIST digit dataset.

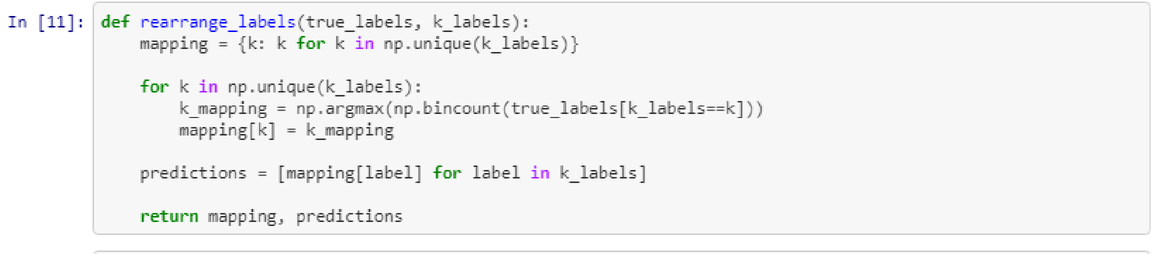
Introduction:

Originally the dataset is meant for classification purposes and is so labeled, as clustering by definition is performed on unlabeled datasets we don’t use labels during training at all. As will be shown in results section, the ‘mean images’ obtained by reshaping the cluster centers into the image dimensions show that the centers appear to have taken the pattern of the digits.

To make sure that the centers have done this we test them with the labels (Again, the labels are not used to train the model only to discover what sort of clusters the model found). We primarily test quality using the KMeans inertia (Objective function)

We also map each of our clusters to a label, by counting the max number of images of a certain label in the cluster and assigning that label to it.

The code snippet to map the labels is below, using this we can map a cluster ‘i’ to a label ‘k’ and see if the mean image of the cluster represents the label so we can have an intuition as to the patterns the model recognized:



In [11]:

```
def rearrange_labels(true_labels, k_labels):
    mapping = {k: k for k in np.unique(k_labels)}

    for k in np.unique(k_labels):
        k_mapping = np.argmax(np.bincount(true_labels[k_labels==k]))
        mapping[k] = k_mapping

    predictions = [mapping[label] for label in k_labels]

    return mapping, predictions
```

Parameters:

We run the program for values of K (5, 7, 10, 12)

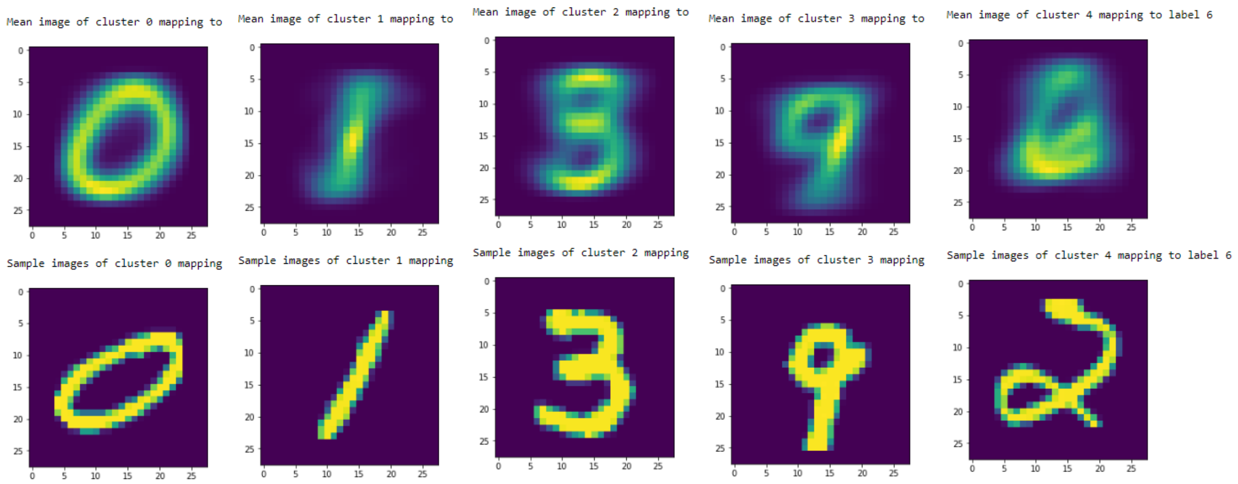
We re-initialize the centroids 5 times for each value of K

We run the program for a maximum number of iterations = 300.

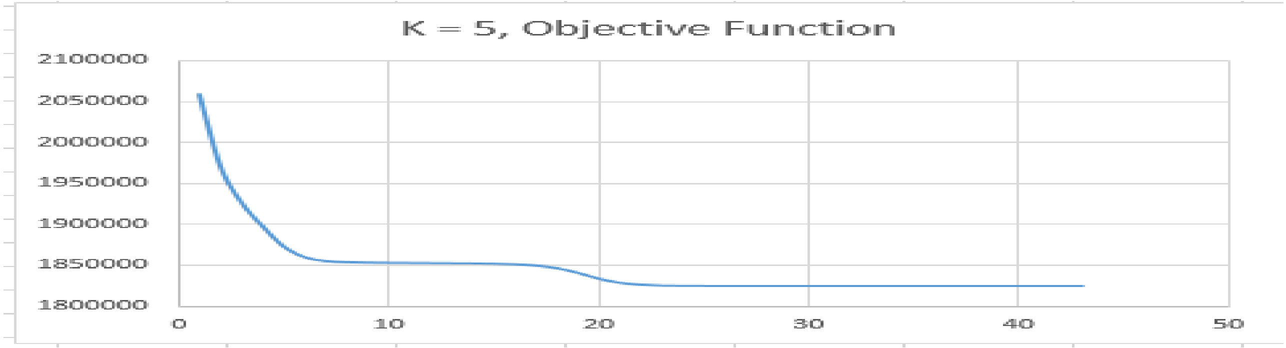
The KMeans algorithm aims to minimize inertia, that is distance between points and their cluster centroids.

Results:

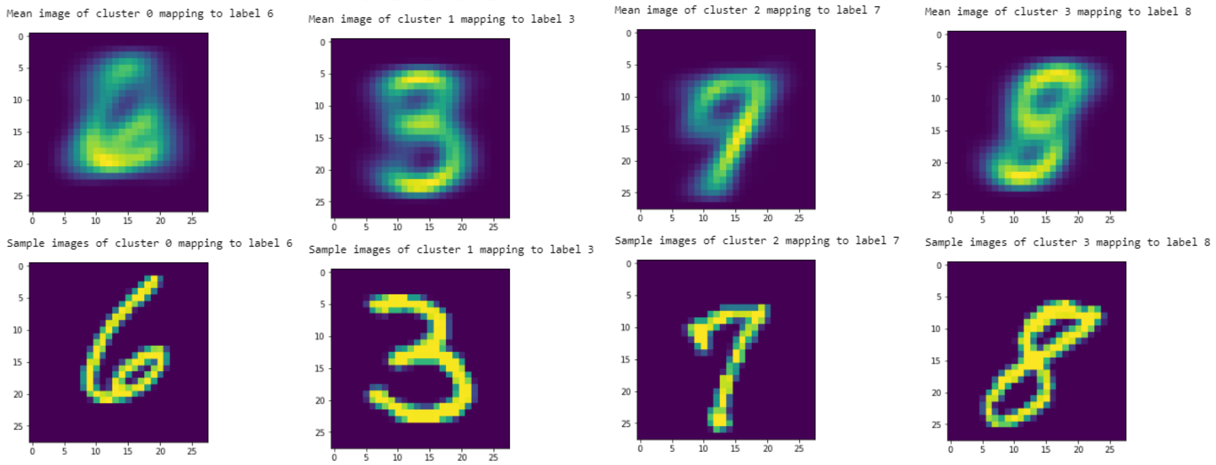
```
For k = 5:
Run1: Max= 2005877.525,        Min= 1824012.219
Run2: Max= 1985790.222,        Min= 1824030.471
Run3: Max= 2058536.885,        Min= 1824011.109
Run4: Max= 2017129.383,        Min= 1824011.315
Run5: Max= 1957515.944,        Min= 1824012.14
Train Accuracy = 0.4511, Test Accuracy = 0.4537
```



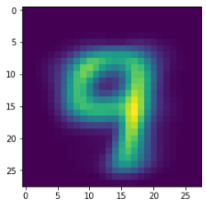
Mappings 0->0, 1->1, 2->3, 3->7, 4->6



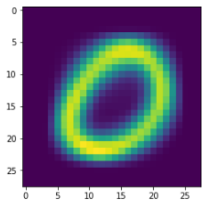
```
For k = 7:
Run1: Max= 1867412.635848724,   Min= 1735097.3918885968
Run2: Max= 1834291.6736012741,  Min= 1735097.9146356802
Run3: Max= 1792639.742930492,   Min= 1735097.4671158127
Run4: Max= 1804453.0941065643,  Min= 1735097.9146356802
Run5: Max= 1834414.5604952567,  Min= 1750063.3164397313
Train Accuracy = 0.5083, Test Accuracy = 0.5064
```



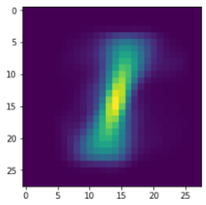
Mean image of cluster 4 mapping to label 4



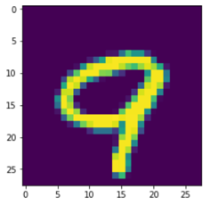
Mean image of cluster 5 mapping to label 0



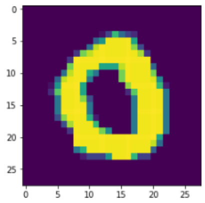
Mean image of cluster 6 mapping to label 1



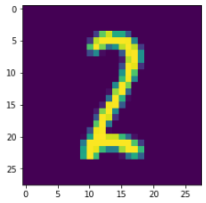
Sample images of cluster 4 mapping to label 4

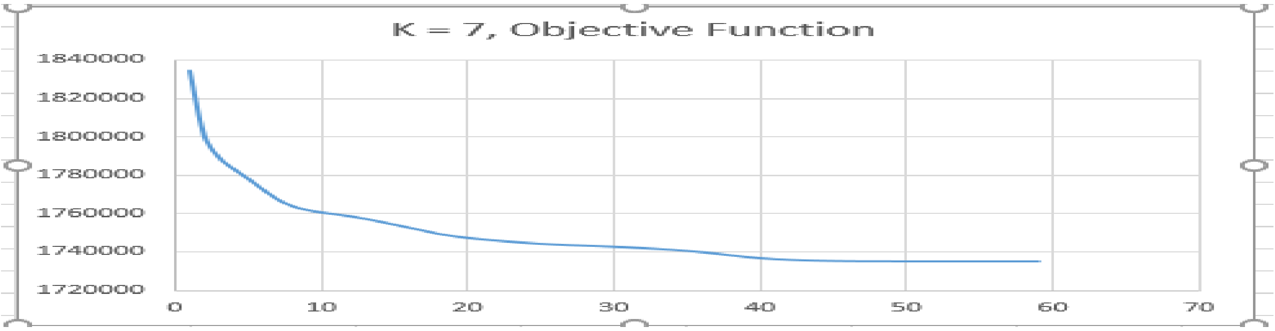


Sample images of cluster 5 mapping to label 0



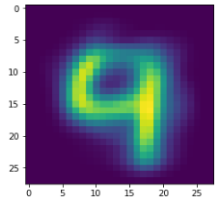
Sample images of cluster 6 mapping to label 1



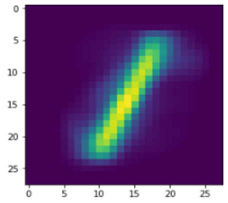


```
For k = 10:
Run1: Max= 1842558.399211303,   Min= 1651141.5429655006
Run2: Max= 1868784.6883395873,  Min= 1646039.2485595671
Run3: Max= 1850150.4099327181,  Min= 1645926.690151455
Run4: Max= 1848641.2613696465,  Min= 1646031.9300724927
Run5: Max= 1824945.3455359973,  Min= 1665512.9291154451
Train Accuracy = 0.5920, Test Accuracy = 0.5883
```

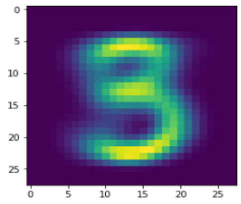
Mean:cluster 0 maps to label 4



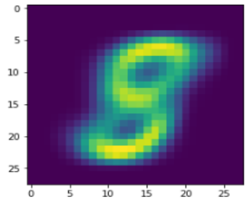
Mean:cluster 1 maps to label 1



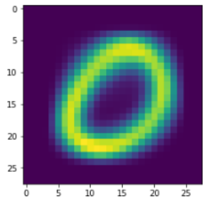
Mean:cluster 2 maps to label 3



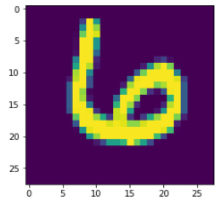
Mean:cluster 3 maps to label 8



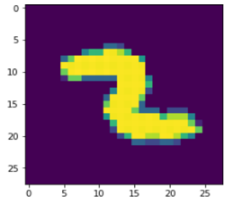
Mean:cluster 4 maps to label 0



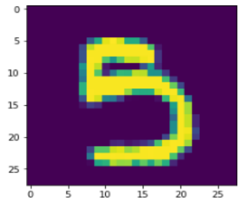
Sample:cluster 0 maps to label 4



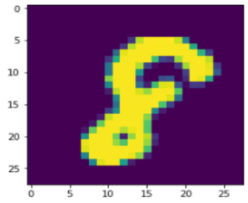
Sample:cluster 1 maps to label 1



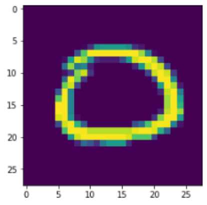
Sample:cluster 2 maps to label 3



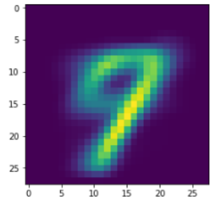
Sample:cluster 3 maps to label 8



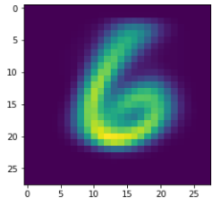
Sample:cluster 4 maps to label 0



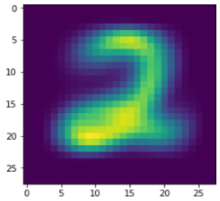
Mean:cluster 5 maps to label 7



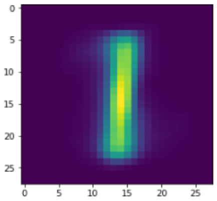
Mean:cluster 6 maps to label 6



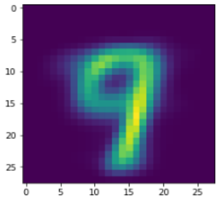
Mean:cluster 7 maps to label 2



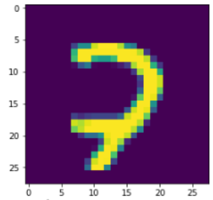
Mean:cluster 8 maps to label 1



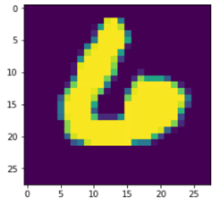
Mean:cluster 9 maps to label 9



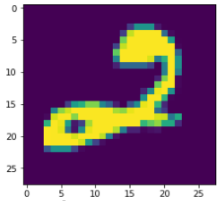
Sample:cluster 5 maps to label 7



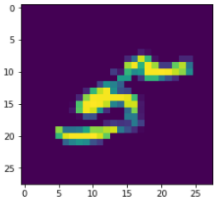
Sample:cluster 6 maps to label 6



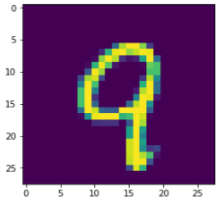
Sample:cluster 7 maps to label 2

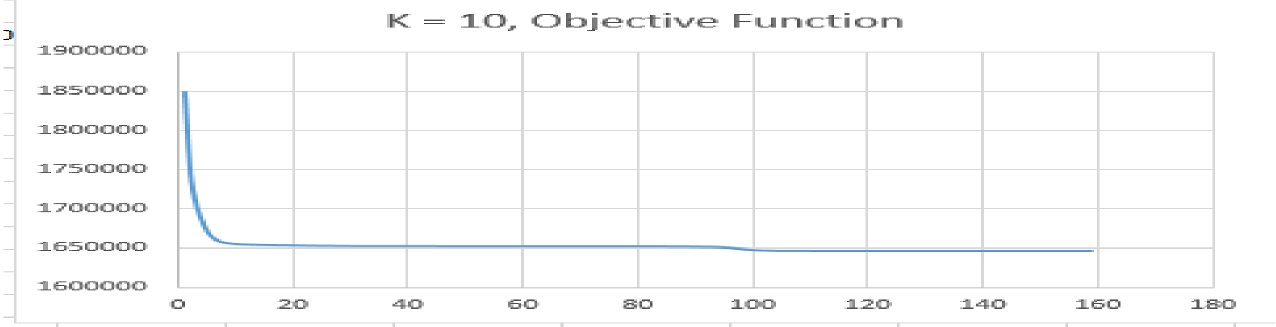


Sample:cluster 8 maps to label 1



Sample:cluster 9 maps to label 9





K = 10, Objective Function

For k = 12:

Run1: Max= 1810431.295040314, Min= 1598411.390134471

Run2: Max= 1806245.0786733285, Min= 1597737.9590808046

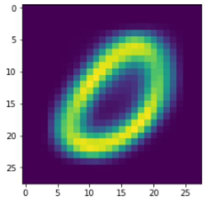
Run3: Max= 1774087.2499047131, Min= 1597737.9511413954

Run4: Max= 1777668.7371507126, Min= 1597737.4860982485

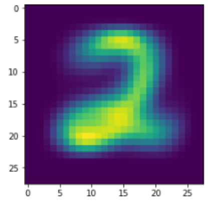
Run5: Max= 1779308.8004898103, Min= 1598417.5902334058

Train Accuracy = 0.6065, Test Accuracy = 0.6035

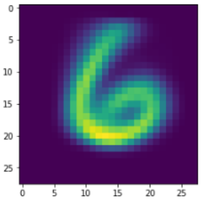
Mean image of cluster 0 mapping to label 0



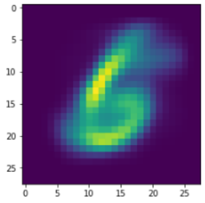
Mean image of cluster 1 mapping to label 2



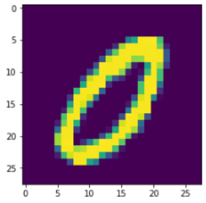
Mean image of cluster 2 mapping to label 6



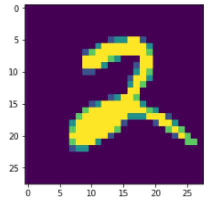
Mean image of cluster 3 mapping to label 6



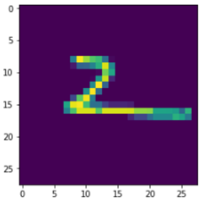
Sample images of cluster 0 mapping to label 0



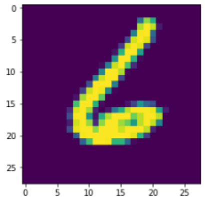
Sample images of cluster 1 mapping to label 2



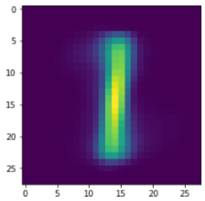
Sample images of cluster 2 mapping to label 6



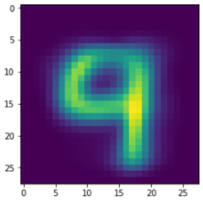
Sample images of cluster 3 mapping to label 6



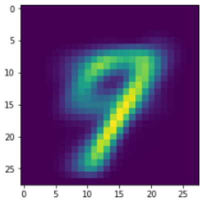
Mean image of cluster 4 mapping to label 1



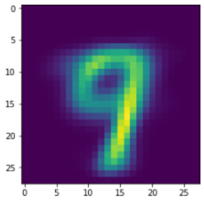
Mean image of cluster 5 mapping to label 4



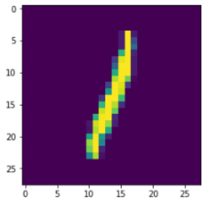
Mean image of cluster 6 mapping to label 7



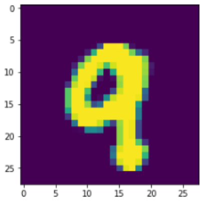
Mean image of cluster 7 mapping to label 7



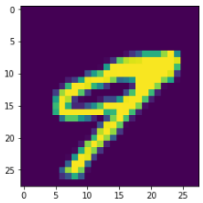
Sample images of cluster 4 mapping to label 1



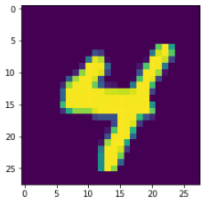
Sample images of cluster 5 mapping to label 4



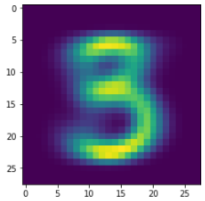
Sample images of cluster 6 mapping to label 7



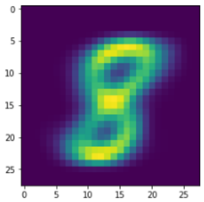
Sample images of cluster 7 mapping to label 7



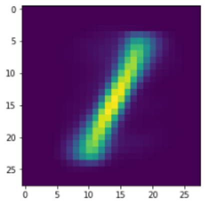
Mean image of cluster 8 mapping to label 3



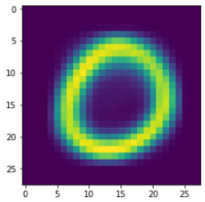
Mean image of cluster 9 mapping to label 8



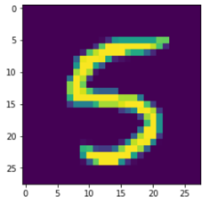
Mean image of cluster 10 mapping to label 1



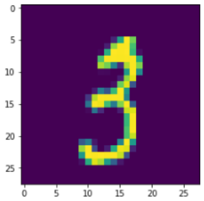
Mean image of cluster 11 mapping to label 0



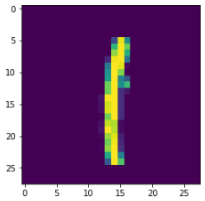
Sample images of cluster 8 mapping to label 3



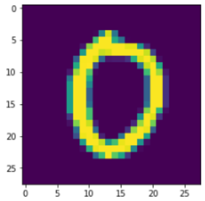
Sample images of cluster 9 mapping to label 8

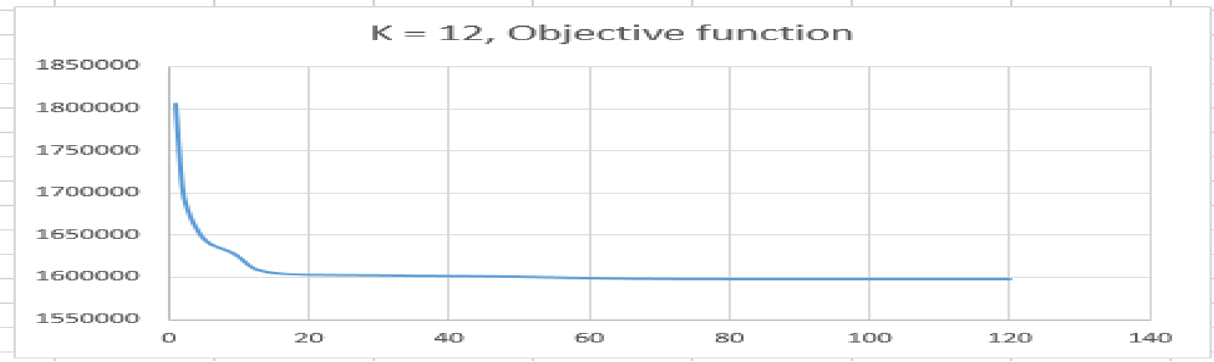


Sample images of cluster 10 mapping to label 1



Sample images of cluster 11 mapping to label 0





Conclusion:

After 300 iterations the model seems to have found mean images corresponding to the digits of the dataset, we ‘inspect’ if the images in the cluster correspond to said digit using the labels and it shows that most of the image in the cluster really correspond to the digit the center mean image shows.