ASSIGNMENT-5

“Classification Accuracy on MNIST handwritten digits data by k-NNC algorithm after doing k-means clustering on the training data"

Submitted By

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Problem Statement

1. Download MNIST handwritten digit data. There are 10 classes (corresponding to digits 0, 1, ..., 9) and each digit is viewed as an image of size 28 × 28 (= 784) pixels; each pixel having values 0 to 255. There are around 6000-digit training patterns and around 1000 test patterns in each class and the class label is also provided for each of the digits. Visit http://yann.lecun.com/exdb/mnist/ for more details.

2. Run K-means algorithm as follows: (a) Consider classes 0 (digit zero) and 1 (digit one). Cluster patterns in each class separately into K clusters using the K-Means algorithm. Use these 2K centroids (K from 0 and K from 1) as training data to classify the test patterns and compute accuracy using the NNC. Vary the value of K from 100 to 500 in steps of 100. (b) Repeat the experiment in step 1 with the pair of classes 7 and 9. (c) Repeat the steps (a) and (b) by clustering the entire data set consisting of both classes 0 and 1. (d) Use the K-Means++ algorithm and repeat steps (a), (b), (c) above.

3. Report your results appropriately using tables and graphs for different scenarios.

4. The report must be brief giving a page on the resources used and how they are used. Two-three pages on the results of your experiments.

Technology and Programming Resources Used

- Spyder Programming Editor
- Python Programming Language 3.7
- Following popular sklearn python libraries for machine learning
    a. sklearn.datasets for fetching MNIST data (fetches data internally from the source web site- http://yann.lecun.com/exdb/mnist/)
    b. Sklearn.cluster import KMeans for K-Means clustering
    c. sklearn.preprocessing for binarizing the data based on below logic
        1. range [0,127] – Binary value 0
        2. range [128,255] – Binary value 1
    d. from sklearn.neighbors import KNeighborsClassifier
    e. matplotlib.pyplot library for plotting charts
- MNIST hand written digit data with
    a. Total Features -784 (pixel grid size- 28x28)
    b. Total Classes- 10 (Digit 0 to Digit 9)
    c. Total Training data- 60000 (6000 per class)
    d. Total Test data- 10000 (1000 per class)
    e. Two pairs of Class data used for experiments- “Class 0 & Class 1” and “Class 7 & Class 9” together

Dataset Pre-Processing: -

Data set – Class 0 & Class 1 data

Training data - First 12,000 records (starting from 0 to 11,999 row indices)
and all 784 feature fields

Training target- First 12,000 records (starting from 0 to 11,999 row indices)
and last785th target field.

Test data – First 2,000 records (starting from 60,000 to 61,999 row
indices) and all 784 feature fields

Test target - First 2,000 records (starting from 60,000 to 61,999 row
indices) and last 785th target field

Data set – Class 7 & Class 9 data

Training data - 6,000 records (starting from 42,000 to 47,999 row indices)
and

6,000 records (starting from 54,000 to 59,999 row indices)
for all 784 feature fields

Training target- 6,000 records (starting from 42,000 to 47,999 row indices)
and 6,000 records (starting from 54,000 to 59,999 row indices)
for last785th target field.

Test data – 1,000 records (starting from 67,000 to 67,999 row indices)
and

1,000 records (starting from 69,000 to 69,999 row indices)
and all 784 feature fields

Test target - 1,000 records (starting from 67,000 to 67,999 row indices)
and 1,000 records (starting from 69,000 to 69,999 row indices)
for last 785th target field

<u>Experiment-1</u>

Check Classification Accuracy for first pair (Class 0 & Class 1) -clustering first and combining later

- Data sets– Class 0 & Class 1 separately
- Program Name- CLASS_0_1_Kmeans.py
- K-means clustering algorithm on Class 0 and Class 1 separately and later combining their clusters in 2K manner for redefining test patterns.
- This algorithm will return reduced number of **new training data patterns** which are cluster centroids.
- Later we need to derive the **new training labels** with the help of actual cluster labels and computing the most common label for training data within each cluster (this requires some look up and counting operation within a program).
- K'-NNC classification algorithm on clustered data set as training data (2K patterns and 2000 Test patterns)
- K = [100,200,300,400,500] (Number of clusters formed on individual class data- 0 & 1)
- 2K = [200,400,600,600,1000] (Combined number of clusters on Class pair- 0 & 1)
- K' = 4 (number of neighbours used in K'-NNC classification algorithm)
- Distance metric in K'-NNC algorithm = L2

Result Table:

Dataset	K value (K-means algorithm)	Accuracy %
Class 0 & 1	200	64.4
Class 0 & 1	400	66.55
Class 0 & 1	600	68.5
Class 0 & 1	800	67.95
Class 0 & 1	1000	66.75

<u>Experiment-2</u>

Check Classification Accuracy for second pair (Class 7 & Class 9) -clustering first and combining later

- Data sets – Class 7 & Class 9 separately
- Program Name- CLASS_7_9_Kmeans.py
- K-means clustering algorithm on Class 7 and Class 9 separately and later combining their clusters in 2K manner for redefining test patterns.
- This algorithm will return reduced number of **new training data patterns** which are cluster centroids.

- Later we need to derive the **new training labels** with the help of actual cluster labels and computing the most common label for training data within each cluster (this requires some look up and counting operation within a program).
- K'-NNC classification algorithm- Fitting clustered data set as new training data and new training labels (2K patterns) and predicting remaining 2000 Test patterns using this model by comparing predicted label and actual labels.
- K = [100,200,300,400,500] (Number of clusters formed on individual class data- 7 & 9)
- 2K = [200,400,600,600,1000] (Combined number of clusters on Class pair- 7 & 9)
- K' = 4 (number of neighbours used in K'-NNC classification algorithm)
- Distance metric in K'-NNC algorithm = L2

Result Table:

Dataset	K value (K-means algorithm)	Accuracy %
Class 7 & 9	200	73.15
Class 7 & 9	400	73.7
Class 7 & 9	600	66.1
Class 7 & 9	800	70.45
Class 7 & 9	1000	75.4

Experiment-3

Check Classification Accuracy for first pair (Class 0 & Class 1) -Combining first and clustering later

- Data set – (Class 0 & Class 1) together
- Program Name- CLASS_0_1_Kmeans.py
- First combining Class 0 and Class 1 together and then K-means clustering algorithm on this data
- This algorithm will return reduced number of **new training data patterns** which are cluster centroids.
- Later we need to derive the **new training labels** with the help of actual cluster labels and computing the most common label for training data within each cluster (this requires some look up and counting operation within a program).
- K'-NNC classification algorithm- Fitting clustered data set as new training data and new training labels (2K patterns) and predicting remaining 2000 Test patterns using this model by comparing predicted label and actual labels.
- K = [100,200,300,400,500] (Number of clusters formed on individual class data- 0 & 1)

- 2K = [200,400,600,600,1000] (Combined number of clusters on Class pair- 0 & 1)
- K' = 4 (number of neighbours used in K'-NNC classification algorithm)
- Distance metric in K'-NNC algorithm = L2

Result Table:

Dataset	K value (K-means algorithm)	Accuracy %
Class 0 & 1	200	84.9
Class 0 & 1	400	88.3
Class 0 & 1	600	89.45
Class 0 & 1	800	89.75
Class 0 & 1	1000	91.45

Experiment-4

Check Classification Accuracy for first pair (Class 7 & Class 9) -Combining first and clustering later

- Data set – (Class 7 & Class 9) together
- Program Name- CLASS_7_9_Kmeans.py
- First combining Class 7 and Class 9 together and then K-means clustering algorithm on this data
- This algorithm will return reduced number of **new training data patterns** which are cluster centroids.
- Later we need to derive the **new training labels** with the help of actual cluster labels and computing the most common label for training data within each cluster (this requires some look up and counting operation within a program).
- K'-NNC classification algorithm- Fitting clustered data set as new training data and new training labels (2K patterns) and predicting remaining 2000 Test patterns using this model by comparing predicted label and actual labels.
- K = [100,200,300,400,500] (Number of clusters formed on individual class data- 7 & 9)
- 2K = [200,400,600,600,1000] (Combined number of clusters on Class pair- 7 & 9)
- K' = 4 (number of neighbours used in K'-NNC classification algorithm)
- Distance metric in K'-NNC algorithm = L2

Result Table:

Dataset	K value (K-means algorithm)	Accuracy %
Class 7 & 9	200	91.7
Class 7 & 9	400	92.6
Class 7 & 9	600	94.9
Class 7 & 9	800	94.15
Class 7 & 9	1000	94.25

Experiment-5

Check Classification Accuracy for first pair (Class 0 & Class 1) -clustering first and combining later

- Data sets– Class 0 & Class 1 separately
- Program Name- CLASS_0_1_Kmeans++.py
- K-means clustering algorithm on Class 0 and Class 1 separately and later combining their clusters in 2K manner for redefining test patterns.
- This algorithm will return reduced number of **new training data patterns** which are cluster centroids.
- Later we need to derive the **new training labels** with the help of actual cluster labels and computing the most common label for training data within each cluster (this requires some look up and counting operation within a program).
- K'-NNC classification algorithm on clustered data set as training data (2K patterns and 2000 Test patterns)
- K = [100,200,300,400,500] (Number of clusters formed on individual class data- 0 & 1)
- 2K = [200,400,600,600,1000] (Combined number of clusters on Class pair- 0 & 1)
- K' = 4 (number of neighbours used in K'-NNC classification algorithm)
- Distance metric in K'-NNC algorithm = L2

Result Table:

Dataset	K value (K-means++ algorithm)	Accuracy %
Class 0 & 1	200	63.45
Class 0 & 1	400	65.75
Class 0 & 1	600	69.65
Class 0 & 1	800	70.55
Class 0 & 1	1000	68.85

Experiment-6

Check Classification Accuracy for second pair (Class 7 & Class 9) -clustering first and combining later

- Data sets – Class 7 & Class 9 separately
- Program Name- CLASS_7_9_Kmeans++.py
- K-means clustering algorithm on Class 7 and Class 9 separately and later combining their clusters in 2K manner for redefining test patterns.
- This algorithm will return reduced number of **new training data patterns** which are cluster centroids.
- Later we need to derive the **new training labels** with the help of actual cluster labels and computing the most common label for training data within each cluster (this requires some look up and counting operation within a program).
- K'-NNC classification algorithm- Fitting clustered data set as new training data and new training labels (2K patterns) and predicting remaining 2000 Test patterns using this model by comparing predicted label and actual labels.
- K = [100,200,300,400,500] (Number of clusters formed on individual class data- 7 & 9)
- 2K = [200,400,600,600,1000] (Combined number of clusters on Class pair- 7 & 9)
- K' = 4 (number of neighbours used in K'-NNC classification algorithm)
- Distance metric in K'-NNC algorithm = L2

Result Table:

Dataset	K value (K-means++ algorithm)	Accuracy %
Class 7 & 9	200	75.4
Class 7 & 9	400	72.5
Class 7 & 9	600	71.05
Class 7 & 9	800	74.8
Class 7 & 9	1000	73.6

Experiment-7

Check Classification Accuracy for first pair (Class 0 & Class 1) -Combining first and clustering later

- Data set – (Class 0 & Class 1) together
- Program Name- CLASS_0_1_Kmeans++.py
- First combining Class 0 and Class 1 together and then K-means++ clustering algorithm on this data
- This algorithm will return reduced number of **new training data patterns** which are cluster centroids.

- Later we need to derive the **new training labels** with the help of actual cluster labels and computing the most common label for training data within each cluster (this requires some look up and counting operation within a program).
- K'-NNC classification algorithm- Fitting clustered data set as new training data and new training labels (2K patterns) and predicting remaining 2000 Test patterns using this model by comparing predicted label and actual labels.
- K = [100,200,300,400,500] (Number of clusters formed on individual class data- 0 & 1)
- 2K = [200,400,600,600,1000] (Combined number of clusters on Class pair- 0 & 1)
- K' = 4 (number of neighbours used in K'-NNC classification algorithm)
- Distance metric in K'-NNC algorithm = L2

Result Table:

Dataset	K value (K-means++ algorithm)	Accuracy %
Class 0 & 1	200	85.75
Class 0 & 1	400	89.25
Class 0 & 1	600	90.4
Class 0 & 1	800	90.95
Class 0 & 1	1000	90.95

Experiment-8

Check Classification Accuracy for first pair (Class 7 & Class 9) -Combining first and clustering later

- Data set – (Class 7 & Class 9) together
- Program Name- CLASS_7_9_Kmeans++.py
- First combining Class 7 and Class 9 together and then K-means++ clustering algorithm on this data
- This algorithm will return reduced number of **new training data patterns** which are cluster centroids.
- Later we need to derive the **new training labels** with the help of actual cluster labels and computing the most common label for training data within each cluster (this requires some look up and counting operation within a program).
- K'-NNC classification algorithm- Fitting clustered data set as new training data and new training labels (2K patterns) and predicting remaining 2000 Test patterns using this model by comparing predicted label and actual labels.
- K = [100,200,300,400,500] (Number of clusters formed on individual class data- 7 & 9)
- 2K = [200,400,600,600,1000] (Combined number of clusters on Class pair- 7 & 9)
- K' = 4 (number of neighbours used in K'-NNC classification algorithm)
- Distance metric in K'-NNC algorithm = L2

Result Table:

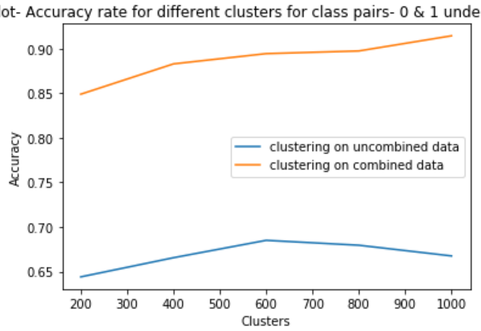
Dataset	K value (K-means++ algorithm)	Accuracy %
Class 7 & 9	200	91.9
Class 7 & 9	400	93.5
Class 7 & 9	600	93.85
Class 7 & 9	800	94.9
Class 7 & 9	1000	95.25

Final Conclusion (combined for all experiments based on the separate results tables and plots):

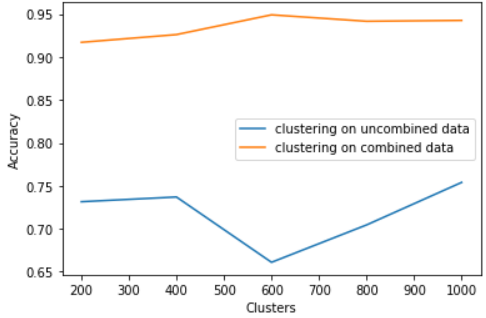
1. Experiments 1 to 4 have a similarity in terms of clustering algorithm- K-means. Similarly, experiments 5 to 8 are using k-means++ for clustering.
2. Experiment 1 to 4, there are couple of things observed-
   - If the data was clustered individually for classes 0, 1 and similarly classes 7 & 9 separately and then later combined, then the k-NNC classification accuracy was low. (). It appears this process introduces more outliers in the training set.
   - Whereas, if the data was combined first for both classes 0, 1 and similarly 7,9 and then clustered, then the k-NNC classification accuracy was high and also model was trained sooner.
3. Experiment 5 to 8 also showed similar trend as point 2 above.
4. K-means++ in general appears to be a better algorithm for clustering by seeing the accuracy rates.
5. Below plots will show the trend.

Plots:

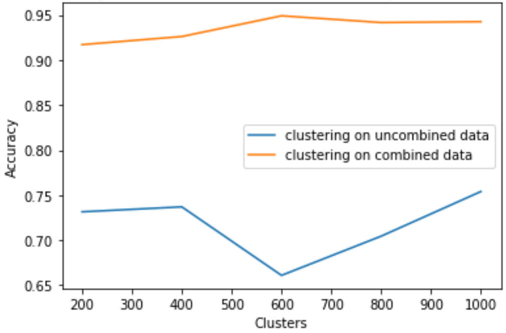
Line Plot- Accuracy rate for different clusters for class pairs- 0 & 1 under k-means++



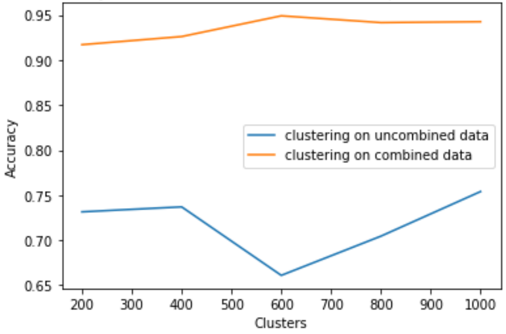
Line Plot- Accuracy rate for different clusters for class pairs- 7 & 9 under k-means++



Line Plot- Accuracy rate for different clusters for class pairs- 7 & 9 under k-means



Line Plot- Accuracy rate for different clusters for class pairs- 7 & 9 under k-means


Accuracy
clustering on uncombined data
clustering on combined data
Clusters