Image Classification & Evaluation by Machine Learning

Mini-Project Presentation

CS5804 Introduction to AI Spring 2022

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Team Members

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Major: Computer Science and Application

Interests: Machine Learning, Deep Learning

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Major: Computer Science and Application

Interests: Machine Learning, Security

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Problem Description

Image classification - one of the major research areas of AI

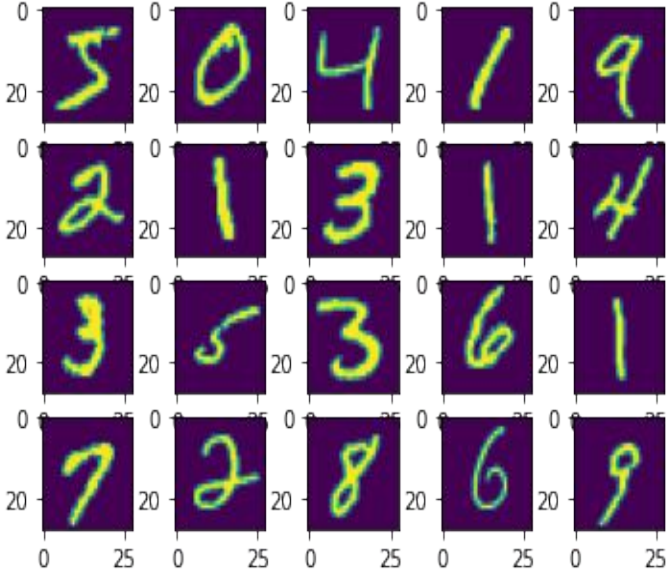
Problem we tackled:

- *Implement* multiple machine learning algorithms to predict the correct digits for handwritten digits in the MNIST dataset
- *Evaluate* and compare their performances
- Lessons learned from the process

Approaches - Dataset

MNIST Dataset

- Include 60,000 handwritten digit images for training
- Include 10,000 test images
- With the true label of the handwritten digit "0-9"



Approaches - Implemented Models

- K-Nearest Neighbors (KNN)
- Neural Network
- K-means based classifier

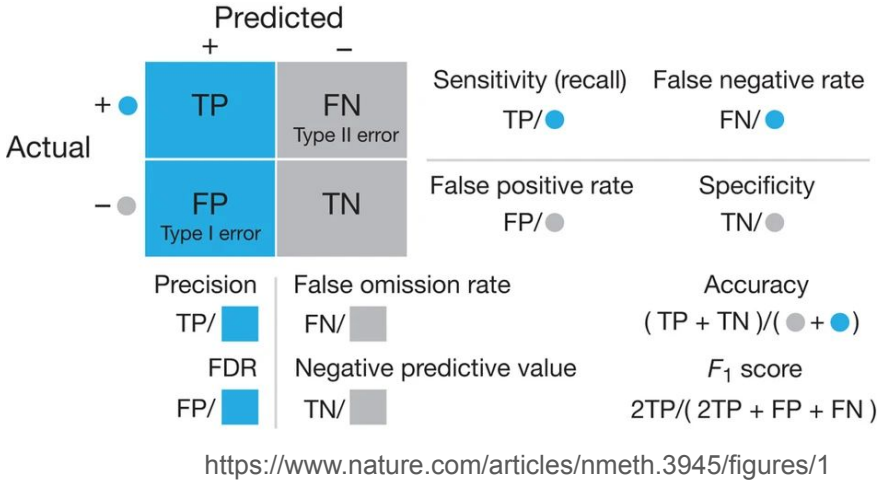
Approaches - Performance Evaluation Metrics

Accuracy: Closeness of measurements to the true value

Precision: The fraction of a cluster that consists of objects of a specified class

Recall: The extent to which a cluster contains all objects of a specified class

F1-score: Harmonic mean of the Precision and Recall



https://www.nature.com/articles/nmeth.3945/figures/1

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K-Nearest Neighbors (KNN)

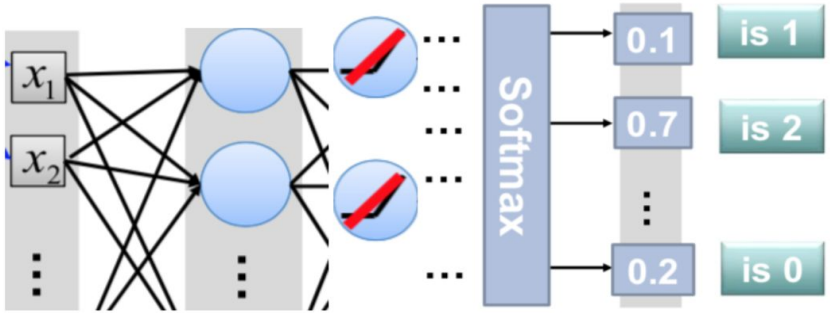
- refers to the k training examples that are close to a test instance, given the test instance
- In this experiment, we use k=245, and euclidean distance

Performance evaluation:

Accuracy	**0.924**
Precision	**0.93**
Recall	**0.923**
F1-score	**0.924**

Neural Network

- build a simple neural network model
- Input layer is the linear transform layer of [784, 10]
- Next layer is the ReLU layer of [10, 10]
- Output layer is the softmax and cross entropy loss layer



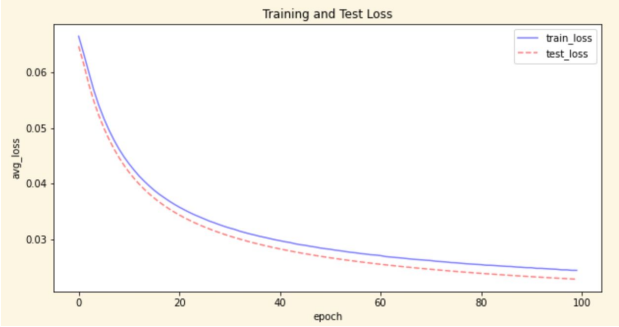
Neural Network (Cont.)

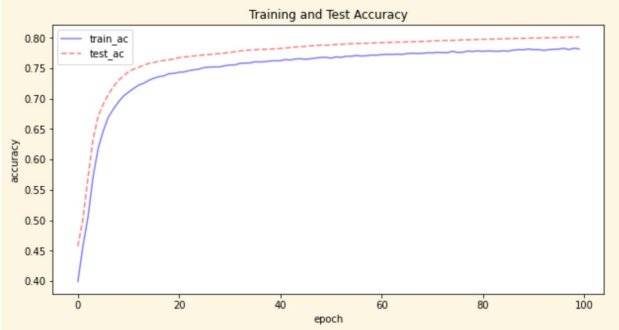
- In this experiment, we set dropout probability to 0.25
- Optimizer is SGD with a Learning Rate=0.0001
- Epoch=100, Batch_size=32

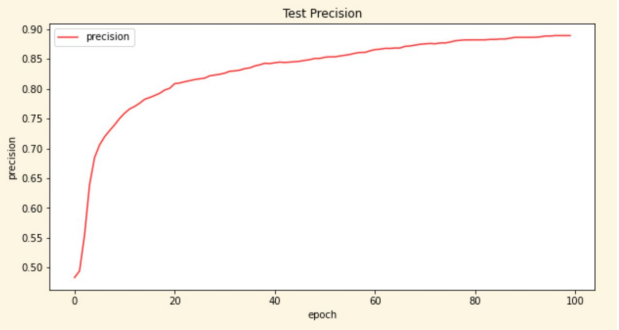
Performance evaluation:

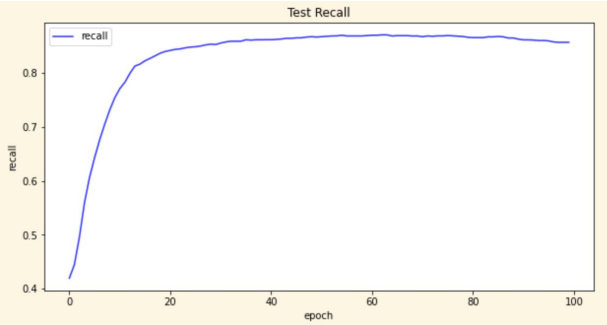
Accuracy	**0.802**
Precision	**0.889**
Recall	**0.857**
F1-score	**0.873**

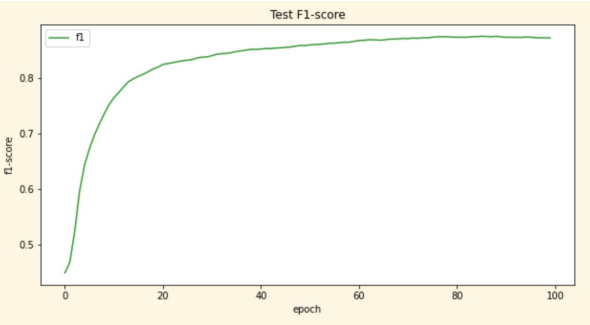
Neural Network (Cont.)











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K-means Clustering based Classifier

- Classifier not based on supervised learning
- Unseen image can be classified through:

1. Form clusters based on the similarity of 28*28 pixel values (updating centroids of each cluster until no centroids change)
2. Make each cluster as a label (digit number)
3. Compute similarity between new unseen data and centroids of all clusters
4. Predict a label of unseen data by choosing the label of the cluster whose centroid is most similar to unseen data's pixel value (lowest difference)

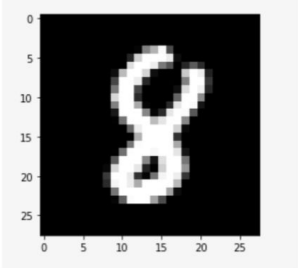
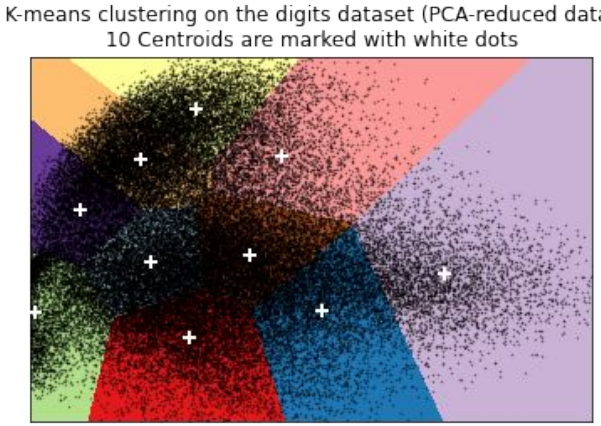
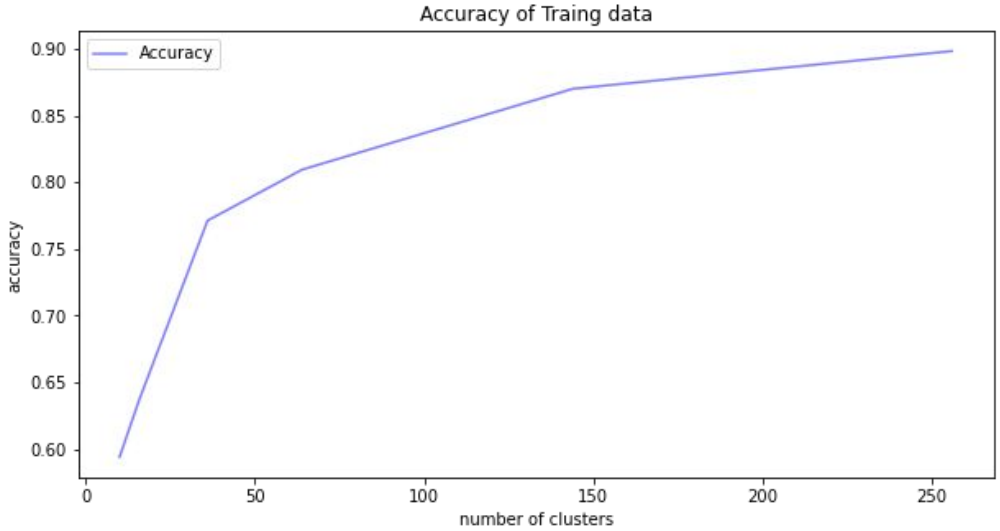


Figure: 28*28 pixel image data in MNIST

K-means Clustering based Classifier

- 10 Cluster was not enough, 256 Clusters was acceptable





- Accuracy for training data: 0.53
- Accuracy for test data: 0.12

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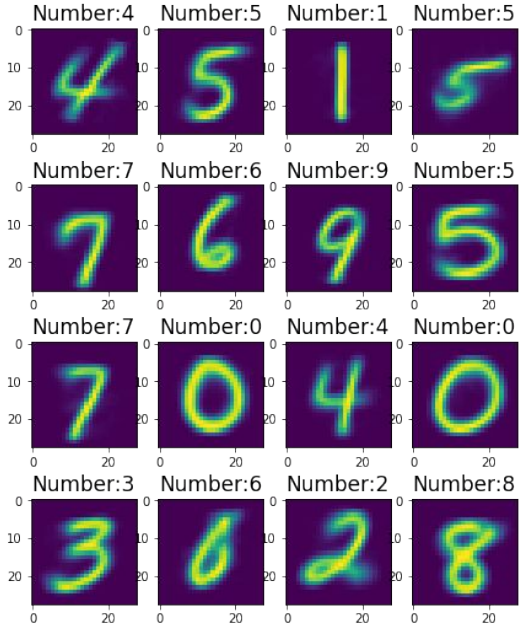
K-means Clustering based Classifier (Cont.)



16 sample Centroids in 256 Clusters

Clusters differ from :

- Number on the image
- Style (font) of the number

Performance evaluation (256 clusters):

Accuracy	**0.895**
Precision	**0.897**
Recall	**0.893**
F1-score	**0.894**

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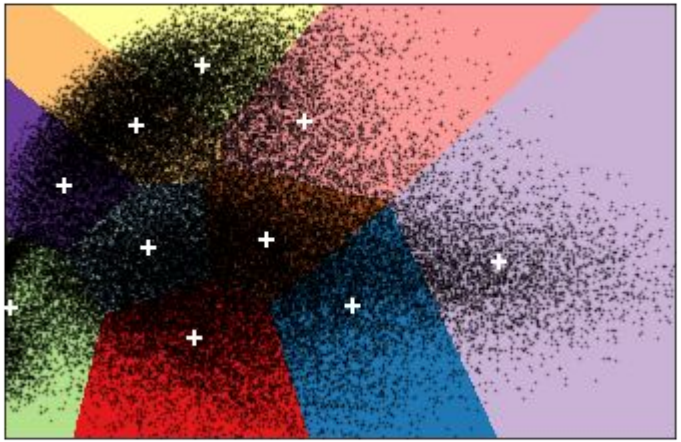
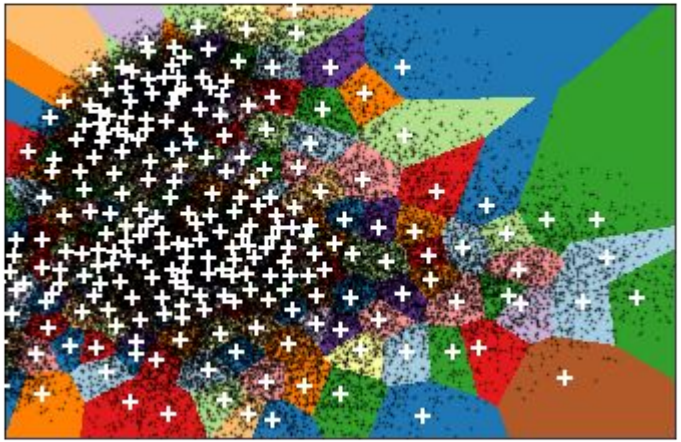
K-means Clustering based Classifier (Cont.)

K-means clustering on the digits dataset (PCA-reduced data)
10 Centroids are marked with white dots



- Accuracy for training data: 0.53
- Accuracy for test data: 0.12

K-means clustering on the digits dataset (PCA-reduced data)
256 Centroids are marked with white dots



- Accuracy for training data: 0.886
- Accuracy for test data: 0.895

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Strength & Weakness of ML algorithms

Metric	KNN	NN	K-means
Accuracy	0.924	0.802	0.895
Precision	0.93	0.889	0.897
Recall	0.923	0.857	0.893
F1-score	0.924	0.873	0.894

Strength:	Best performance Lowest computation cost	*Likely to be improved when problem become more complicated*	Acceptable performance based on unsupervised learning
Weakness:	*Likely to be degraded when problem become more complicated*	Worst performance Highest computation cost	Difficult to manipulate decision boundaries and set # of clusters Sensitive to Outliers

Lesson Learned

- Neural network is known to be one of the best ML algorithm, but didn't make the best performance in this project
- There is no absolutely superior ML algorithms for all problems
- If you plan to use a ML model, choosing ML algorithm appropriate to the characteristics of the problem is important
- Preprocessing a dataset is as difficult task as making a machine learning model

Future Work

- Develop a KNN classifier using cosine similarity for the similarity calculation, instead of euclidean distance
- Performance evaluation of the convolutional neural network (CNN) model and the difference between various hyper parameter settings
- Develop a classifier taking advantage of **K-means clustering** and supervised learning algorithm (e.g. **KNN**, Logistic regression) , which performs better than the supervised learning alone.

Thank you!