CS523 Computer Vision
Report

Sudoku Digit Recognition and Classification

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Introduction

This report explains the implementation details of CS523 Computer Vision Assignment 2, which is about training a kNN classifier on the MNIST dataset, reducing the dimensions with Principal Component Analysis(PCA) and using the classifier on the Sudoku Dataset to recognize the digits. I will explain the idea behind PCA for reducing the dimensions, the kNN classifier, processing methods I have used to extract digits from the Sudoku Dataset and lastly comment on my results.

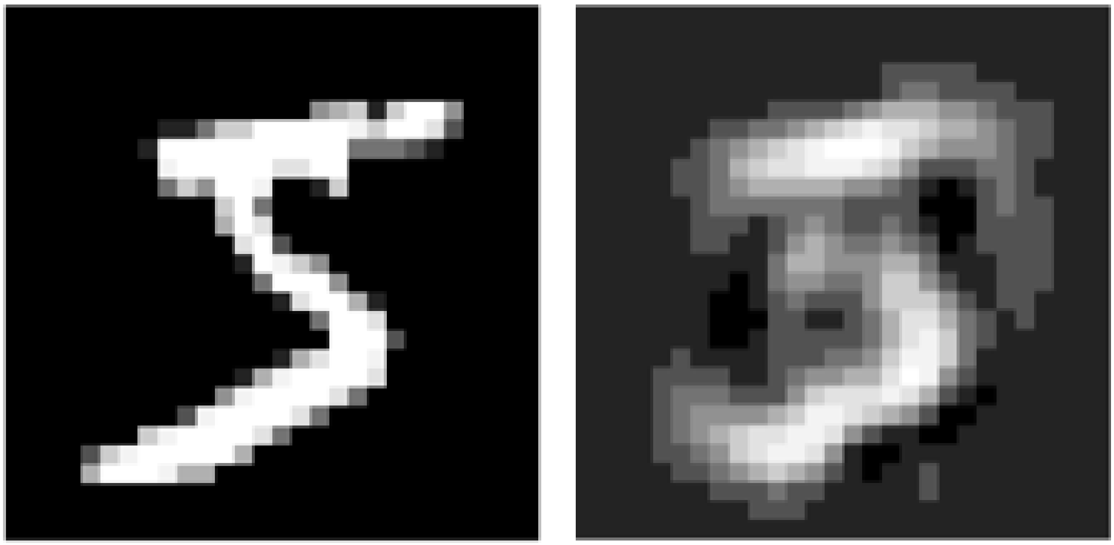
To run the code, there needs to be an images directory where the .dat files and .jpg files are located. Also python-mnist needs to be installed to load the MNIST dataset into numpy arrays.

Principal Component Analysis

Principal Component Analysis(PCA) is an algorithm used for dimensionality reduction. In the MNIST hand written digits dataset, each image comes as vectors of dimension 784. However, we do not need all the dimensions contain classifying an image. The idea is, compressing a matrix with a lot of features into a smaller matrix, with less features which preserves as much of the information in the full matrix as possible.

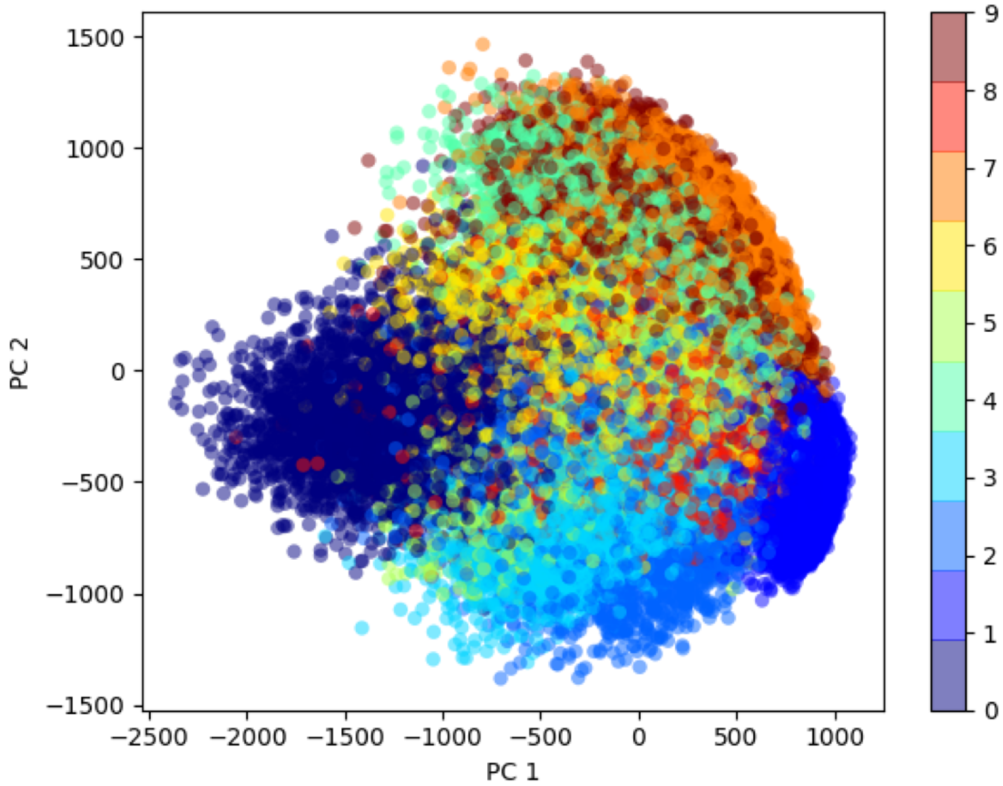
In my PCA algorithm, to get the eigen vectors, I first calculated the mean values of each column and centered the values I found by subtracting the mean column value. Afterwards, I calculated the covariance matrix of the centered matrix. Than, I calculated the eigen values and eigen vectors with and than finally, sorted them with respect to their eigen value magnitudes.

To get the reduced versions of the images, I projected both train images and test images on their first 25 principal components by a matrix multiplication. To visualize the results, I used a function I found online to reconstruct the first image of the MNIST dataset from its principal components and ended up with the following image.



PCA results

To observe the clustering, I projected the train images onto their first two principal components and produced a scatter plot.



PCA results

k-Nearest Neighbor Algorithm

k-Nearest Neighbors is a simple classification algorithm that stores all available cases and classifies new cases based on a similarity measure.

After reducing the dimensions from 784 to 25, I computed the distances between X_test and X_train to prepare my data for kNN classifier. To compute the distances, I first used a nested for loop but ended up waiting 30 minutes for computing the distances between train data and test data. To compute the distances without any loops, I converted my nested for loops to a matrix multiplication with two broadcast sums.

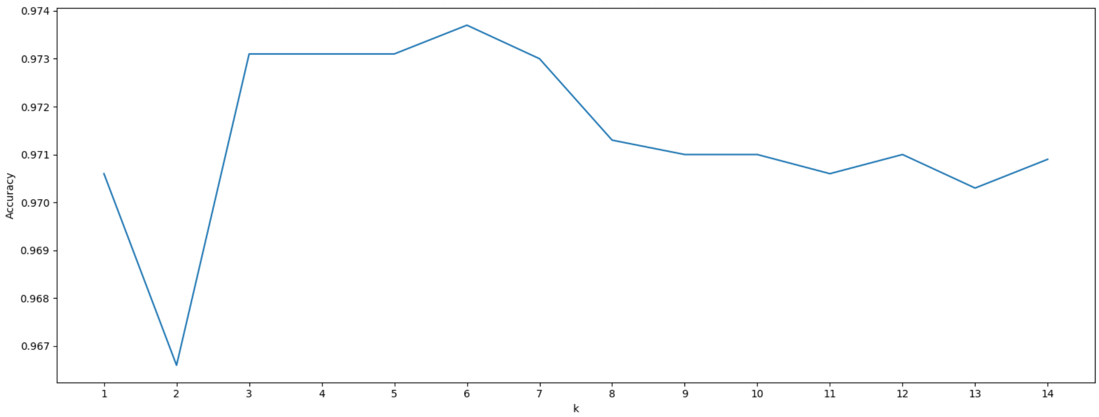
```
 dists = np.reshape(np.sum(X**2, axis=1), [num_test,1]) + np.sum(
X_train**2, axis=1) \
          - 2 * np.matmul(X, X_train.T)
 dists = np.sqrt(dists)
```

Listing 1: Computing the distances without loops

After computing the distances and obtaining a distance matrix, I looped over the test data and used the distance matrix to find k nearest neighbors of the ith testing point.

Than I used the train labels to find the neighbors of the found labels and than obtained the most common labels.

To find the best k value for the classification of the MNIST dataset, I looped over k values from 0 to 15 and plotted the following graph to visualize my findings. Lastly, I calculated the confusion matrix for 6 neighbors.



Prediction accuracy of kNN Classifier
as a function of k (Number of Neighbours)

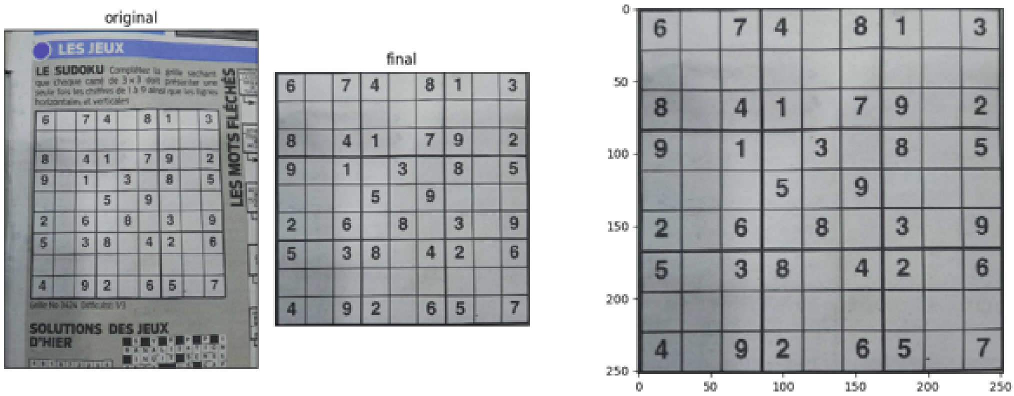
Predicted	0	1	2	3	4	5	6	7	8	9	All
Actual											
0	975	1	1	0	0	1	1	1	0	0	980
1	0	1131	1	0	0	0	3	0	0	0	1135
2	7	1	1003	0	1	0	3	11	6	0	1032
3	0	2	4	973	0	13	0	6	10	2	1010
4	0	0	0	0	960	0	4	2	0	16	982
5	3	2	1	9	1	868	5	1	1	1	892
6	4	4	0	0	3	0	947	0	0	0	958
7	1	20	10	0	2	0	0	985	0	10	1028
8	3	0	3	14	4	5	1	2	938	4	974
9	4	3	3	10	14	6	1	7	4	957	1009
All	997	1164	1026	1006	985	893	965	1015	959	990	10000

Confusion Matrix of kNN classifier with 6 neighbors
Accuracy: 97.37%

Sudoku Digit Extraction

At the end of my assignment 1, I was able to find contours in a given sudoku image. To use the kNN classifier on each digit on the Sudoku Dataset to get the digits, I needed to do some processing. First I did a perspective transform to obtain a bird eye view of the sudoku grid.

Afterwards I resized the transformed image to 252 x 252 so that I can iterate over the pixels of the image with a 28 x 28 box.



Original,wrapped and Resized Sudoku Grid

I iterated over image and extracted each 28 by 28 square and projected them onto their first 25 principal components using the principal components I have computed at the beginning. I repeated the steps that I have followed for computing the distances and predicting the labels this time for the extracted pieces from the sudoku grid.

Results

I can say that the PCA for dimensionality reduction worked really well. In the scatter plot, it is easy to see the clustering. The kNN algorithm also did a great job in classifying the test images with an accuracy of 97.37%.