# CS 215 Assignment 4 Report

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## Problem 3

### Assumptions while running code

- The training data-set is used
- The `.gz` files are provided uncompressed, and the extracted train-images and train-labels are present in the same folder as the code

### Part a

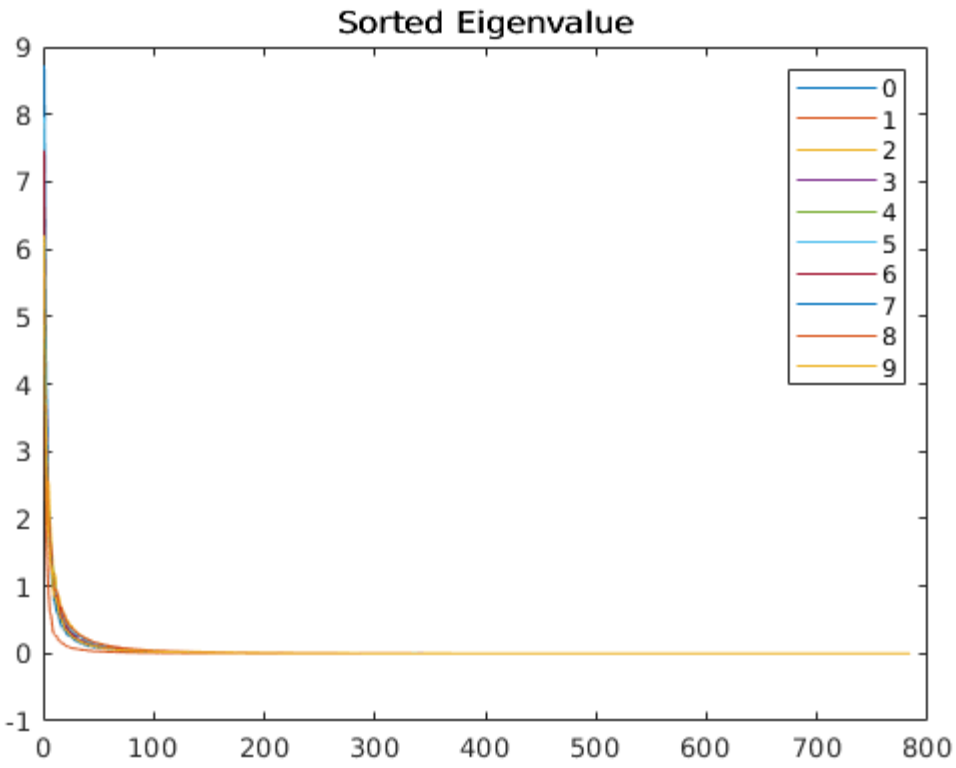
If we define number of principal modes of variation as the number of modes of variation that capture at least 90% of the variance of the data, i.e. $n$ such that $\frac{\sum_{i=1}^{n} \Lambda ii}{\sum_{i=1}^{N} \Lambda ii} \geq 0.9$, then we get the following

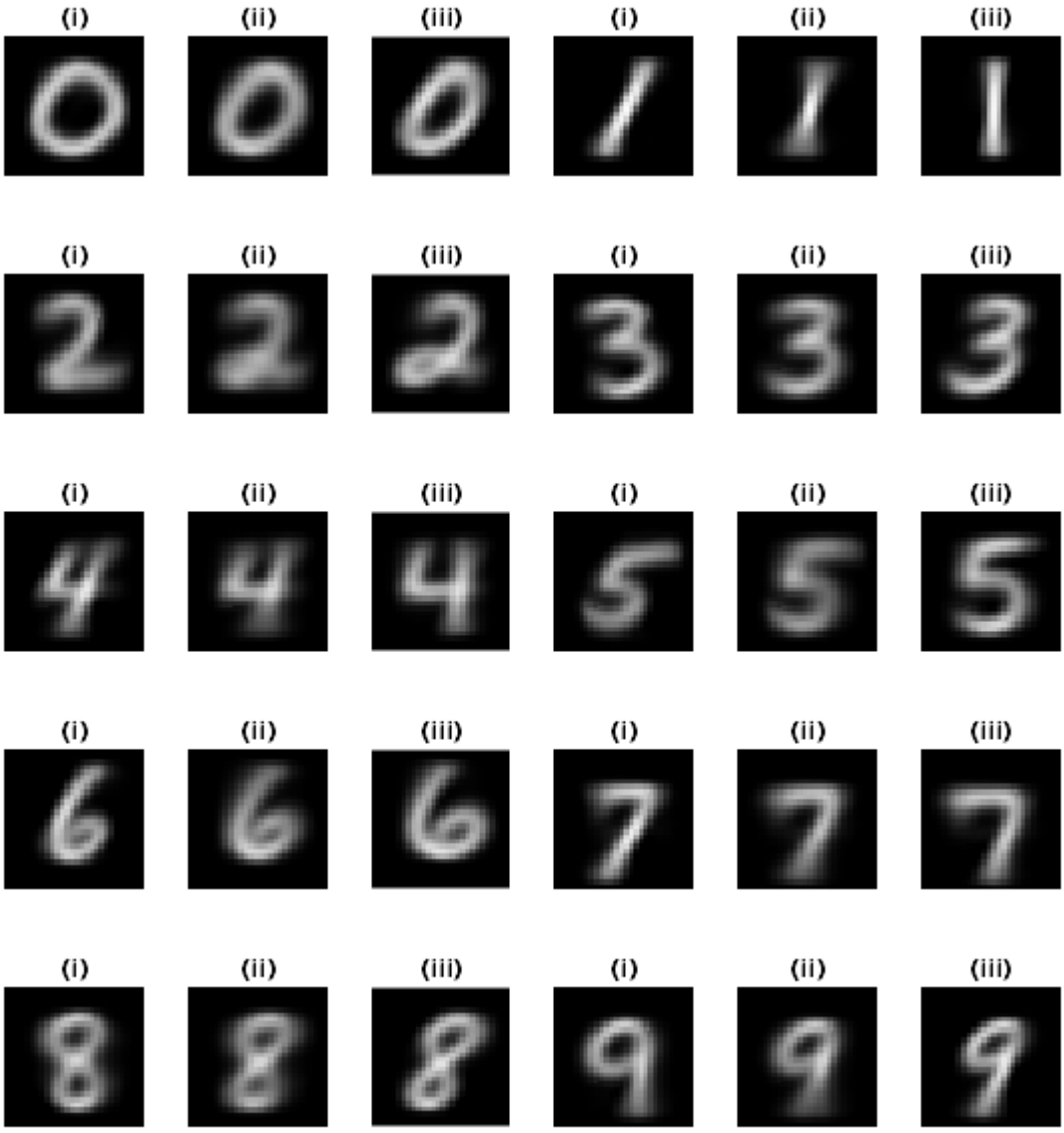
| Digit | No. of principal modes of variation |
|---|---|
| 0 | 62 |
| 1 | 36 |
| 2 | 81 |
| 3 | 80 |
| 4 | 76 |
| 5 | 75 |
| 6 | 62 |
| 7 | 66 |
| 8 | 82 |
| 9 | 62 |

The number of principal modes of variation is far less than $28^2 (= 784)$ for all the digits. This because in real-world images neighbouring pixels usually have a high correlation and hence the actual degrees of freedom is far lesser than the actual number of pixels.

### Part b

The middle figures show the mean of all the images, i.e. it represents on an average the ways how people write a particular digit. The left and right images show the deviations from the average ways of writing a digit along the direction of maximum deviation. For the digit 1, we observe that amongst the various ways that people write it, the most significant variation is in the tilt of the digit and on the two extremes, people write it as tilted towards the right or vertical. Thus, the principal mode represents how tilted is 1 written, and the two images show the range of angles between which most people write 1. Similarly for other digits.


Sorted Eigenvalue
9
8
7
6
5
4
3
2
1
0
-1
0
100
200
300
400
500
600
700
800
0
1
2
3
4
5
6
7
8
9


(i) (ii) (iii) (i) (ii) (iii)
(i) (ii) (iii) (i) (ii) (iii)
(i) (ii) (iii) (i) (ii) (iii)
(i) (ii) (iii) (i) (ii) (iii)
(i) (ii) (iii) (i) (ii) (iii)