Face Recognition using PCA and Eigenfaces

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1 Introduction

This project explores the application of Principal Component Analysis (PCA) for face recognition. The key idea is to represent faces using a reduced-dimensional subspace spanned by *eigenfaces*, which are the eigenvectors of the covariance matrix of the dataset. This reduces noise, improves recognition efficiency, and highlights the most important features of the faces.

2 Dataset Summary

Samples: 400 total (320 train, 80 test)
Identities/Classes: 40
Image size: 112×92 (vector dim = 10304)

3 Methodology

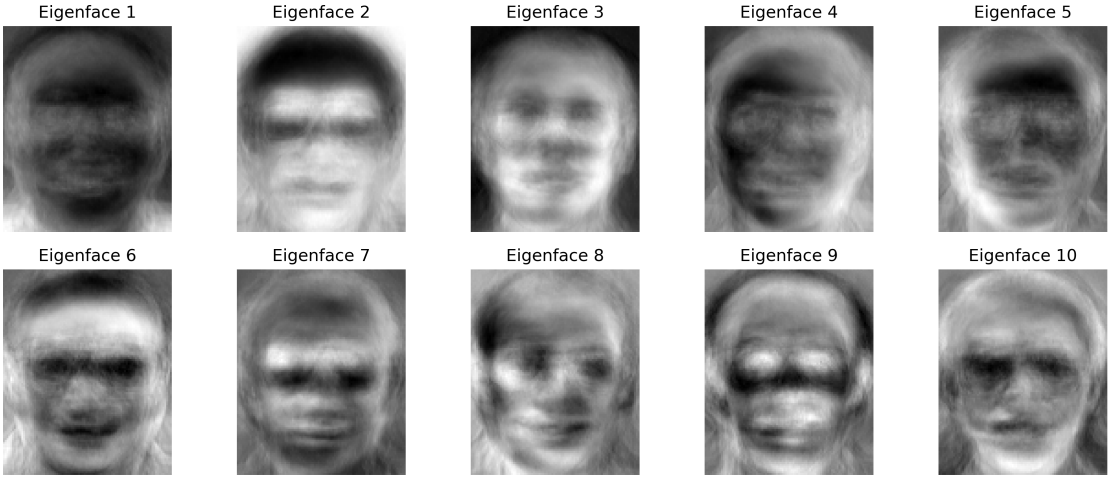
The workflow consisted of the following steps:

1. Compute the mean face and subtract it from all images (mean centering).
2. Calculate the eigenvectors (eigenfaces) of the covariance matrix.
3. Select the top-k eigenfaces based on eigenvalues.
4. Project images into the PCA subspace.
5. Reconstruct images using different values of k.
6. Train a nearest neighbor classifier in the PCA space.
7. Evaluate reconstruction error and recognition accuracy.

4 Results

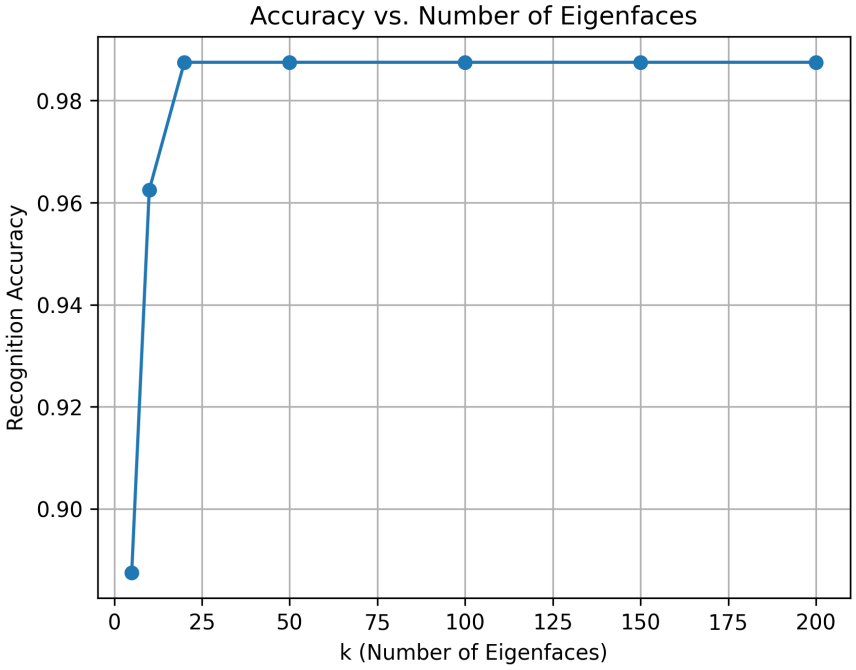
4.1 Mean Face

4.2 Eigenfaces



4.3 Reconstruction with Different k

4.4 Recognition Accuracy vs k



4.5 Numerical Results

k	Reconstruction MSE	Recognition Accuracy
5	0.5243	0.8875
10	0.4071	0.9625
20	0.3033	0.9875
50	0.1803	0.9875
100	0.1803	0.9875
150	0.1803	0.9875
200	0.1803	0.9875

Table 1: Comparison of reconstruction error and recognition accuracy for different k.

5 Discussion

The results clearly indicate a trade-off between reconstruction quality and dimensionality. With very few eigenfaces ($k = 5$), both reconstruction quality and recognition accuracy are poor. As k increases, the reconstruction mean squared error (MSE) decreases significantly, and recognition accuracy improves rapidly. Beyond $k = 20$, the recognition accuracy stabilizes around 98.75%, while reconstruction error saturates at around 0.1803. This suggests that most discriminative information is captured within the first 20–50 eigenfaces.

6 Conclusion

This experiment demonstrates that PCA with eigenfaces is highly effective for face recognition. The optimal performance is achieved with around $k = 20$ eigenfaces, balancing accuracy and computational efficiency. Adding more eigenfaces does not significantly improve recognition accuracy, but increases computation and storage requirements. Thus, dimensionality reduction using PCA provides both theoretical and practical benefits in face recognition systems.