Eigenfaces for Face Recognition: PCA-Based Analysis on ORL Dataset

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***Abstract*—This project implements the Eigenfaces method for face recognition based on Principal Component Analysis (PCA) using the ORL face dataset. We walk through five stages: preprocessing, PCA and eigenface generation, face reconstruction, classification, and robustness to noise. The results demonstrate the effectiveness of PCA in dimensionality reduction and facial identity encoding.**

I. Introduction

Face recognition is a widely researched topic in computer vision. The Eigenfaces method, introduced by Turk and Pentland [1], uses PCA to reduce high-dimensional facial image data to a lower-dimensional space while preserving significant identity-relevant features. This paper evaluates the method across five tasks and experiments using the ORL dataset.

II. Task 1: Data Preprocessing

All images were resized to 112×92 and converted to grayscale vectors. The mean face was calculated for both the entire dataset and a subset of 10 images.

Fig. 1. Mean face from all images (left) vs subset (right)

III. Task 2: PCA and Eigenfaces

We applied PCA to compute the eigenvectors of the covariance matrix of centered data. These eigenvectors (Eigenfaces) capture the most significant variance directions in the dataset.

IV. Task 3: Face Reconstruction

Using top M eigenfaces, we reconstructed original faces for $s10$ and $s11$. The quality increases with M, while Mean Squared Error (MSE) decreases.

V. Task 4: Classification with Eigenfaces

Face recognition was performed using nearest neighbor classification in eigenface space. We achieved up to 98.5% accuracy.

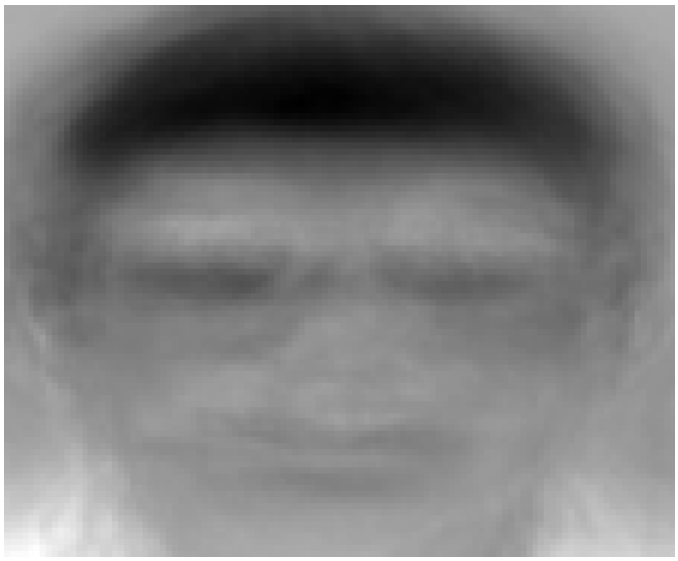

Fig. 2. Top Eigenface (ef_0_10.png). Resembles a "ghostly" average face.

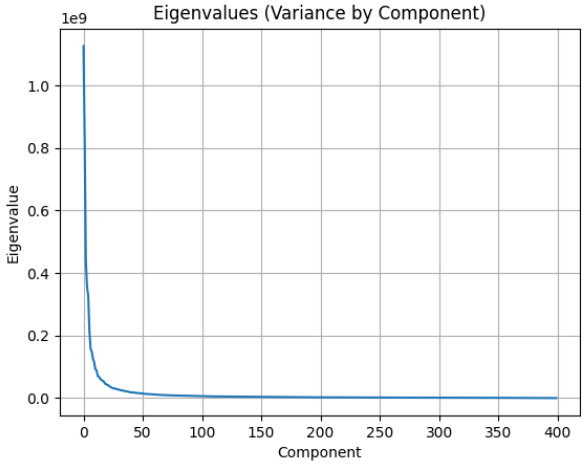

Fig. 3. Eigenvalues plotted against principal component index

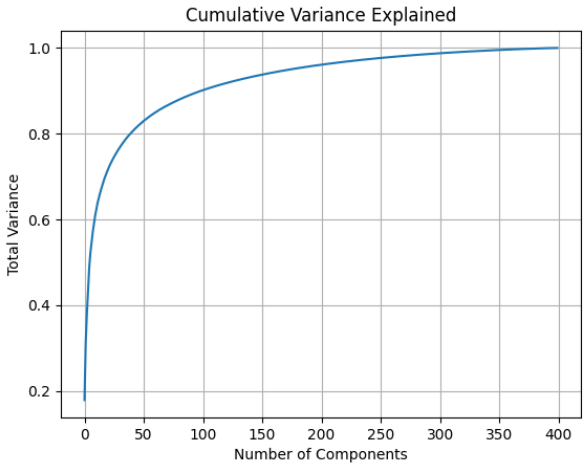

Fig. 4. Cumulative variance: 95% achieved with first 100 components

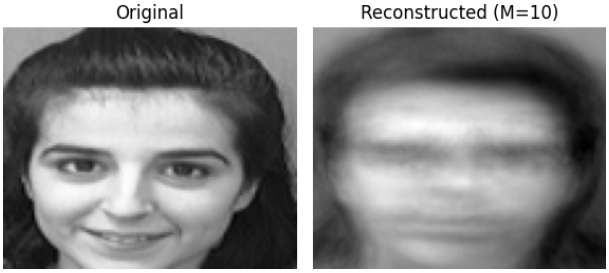

Fig. 5. Reconstruction with M=10 (left: original, right: blurry)

VI. Task 5: Robustness to Noise

Recognition accuracy was tested under Gaussian and Salt-and-Pepper noise with M=50. The system showed strong robustness to Gaussian noise up to std=0.5 and to Salt-and-Pepper noise up to 0.4.

VII. Conclusion

This project demonstrates that PCA-based Eigenfaces provide a powerful yet simple method for face recognition. The system achieves high recognition accuracy and is resilient to noise. Higher values of M improve reconstruction and classification but introduce computational costs. An optimal

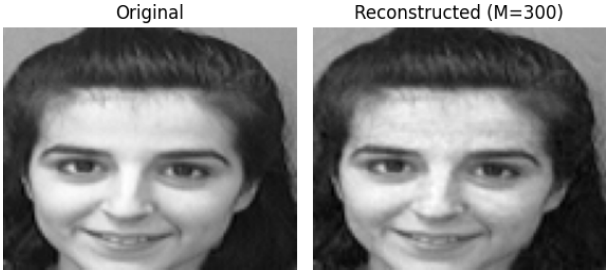

Fig. 6. Reconstruction with M=300 (right nearly indistinguishable from original)

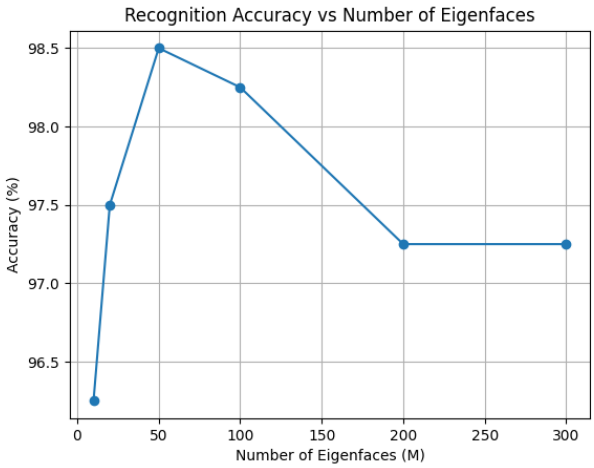

Fig. 7. Recognition accuracy vs number of eigenfaces

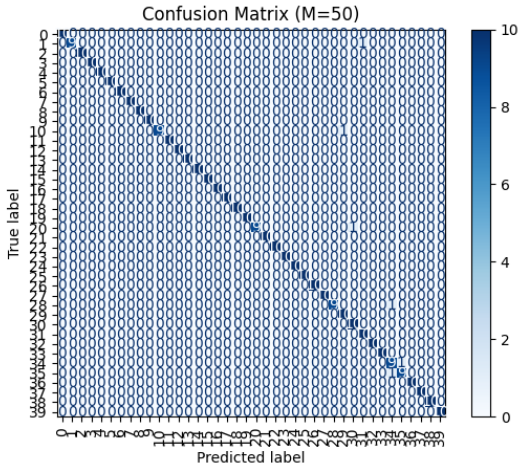

Fig. 8. Confusion matrix for M=50

Fig. 9. Salt-and-pepper noise: light (left) vs heavy (right)

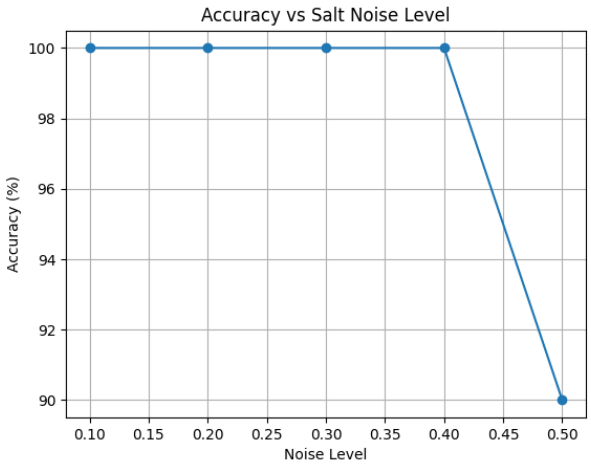

Fig. 10. Accuracy vs Salt-and-Pepper noise level

balance around $M = 50$–100 is often sufficient for practical systems.

REFERENCES

[1] M. Turk and A. Pentland, "Eigenfaces for recognition," *Journal of cognitive neuroscience*, vol. 3, no. 1, pp. 71–86, 1991.