Dimensionality Reduction & Classification

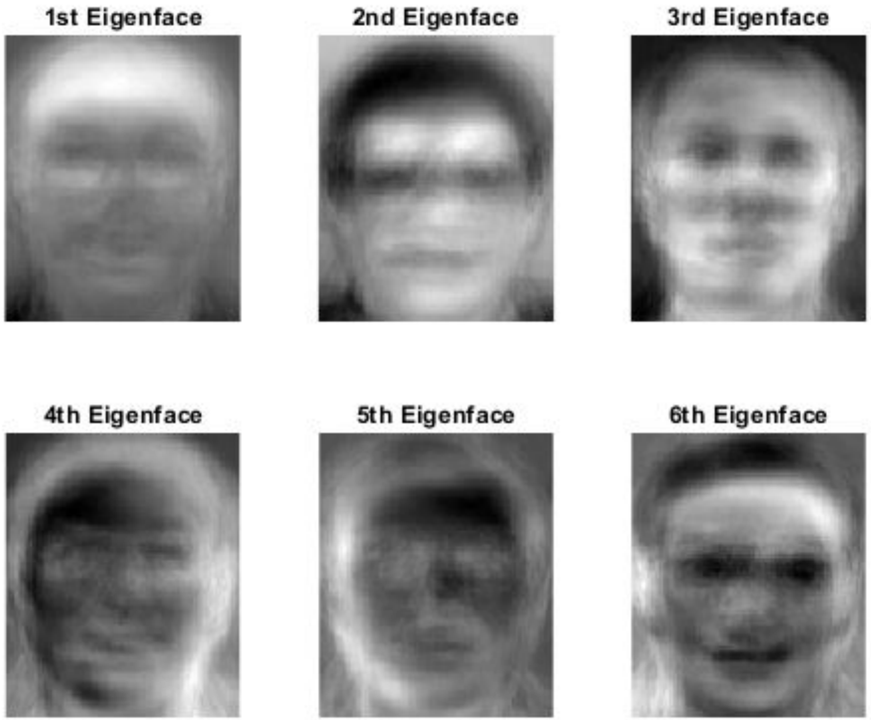
Project 4 - CISC 820 Quantitative Foundations

Presented by:

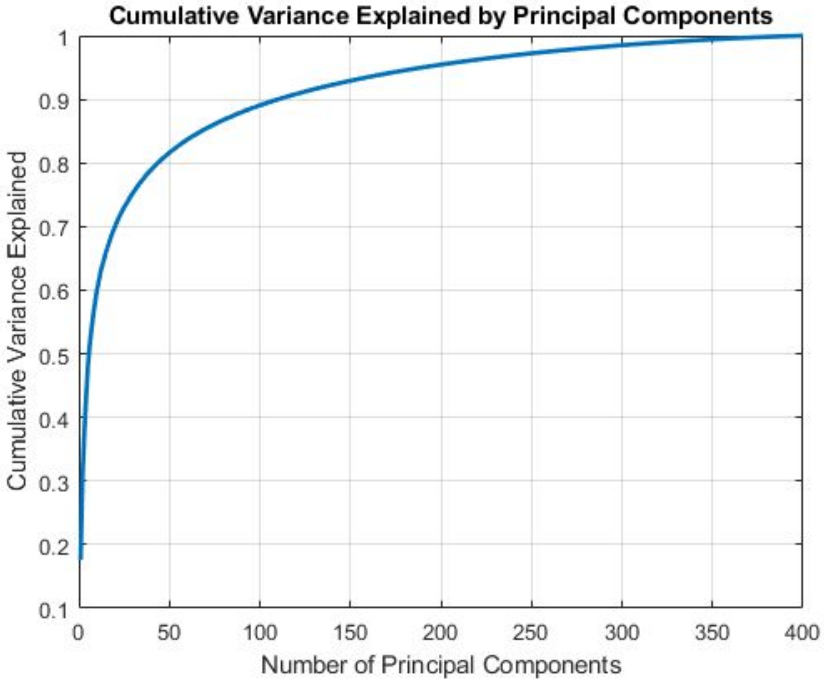
Image Adhikari, Ester Chen

Dimensionality reduction
Using PCA to extract eigenfaces

How do the leading eigenfaces look like as an image?



How does the importance of the eigenfaces decrease?



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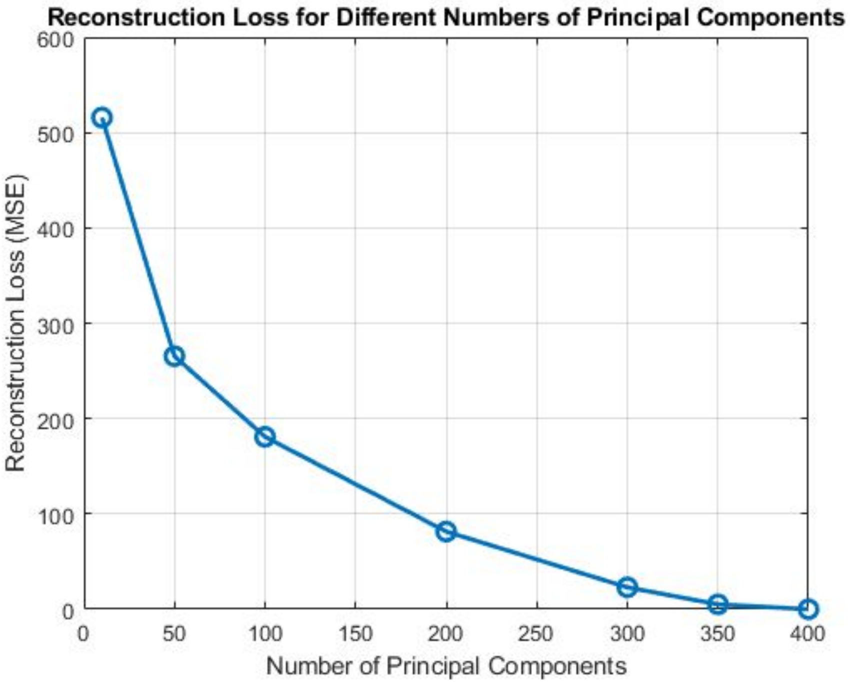
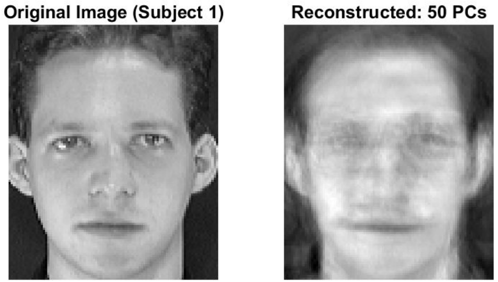
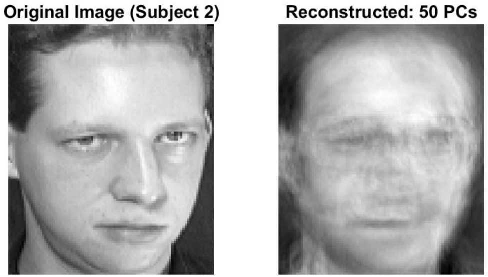
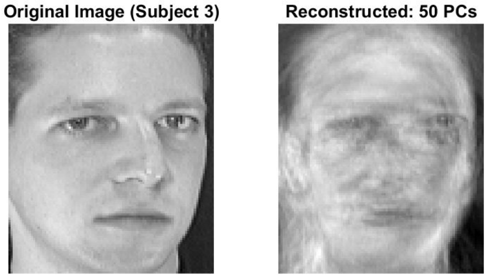


Face Reconstruction with PCA

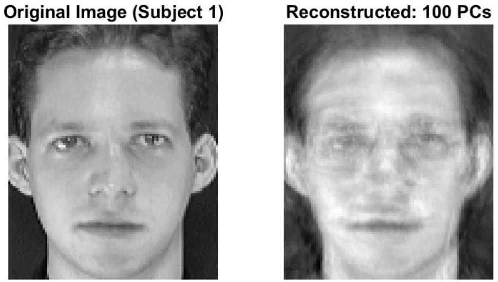
Differences between reconstructed and original images using 50 Eigenfaces

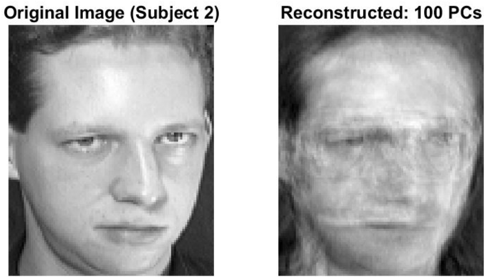


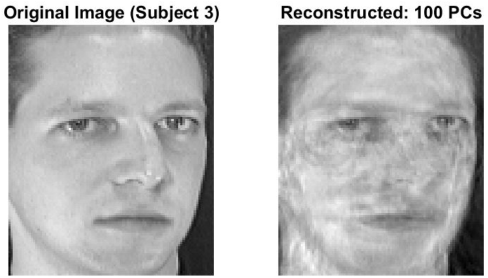




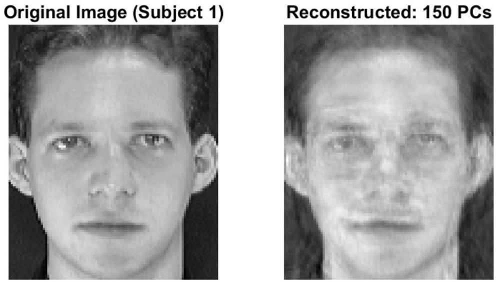
Differences between reconstructed and original images using 100 Eigenfaces

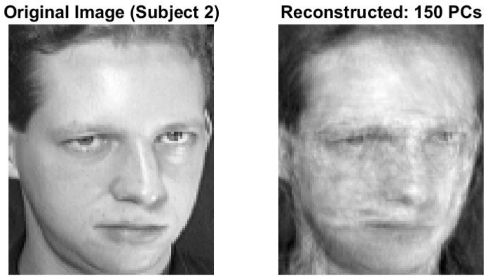


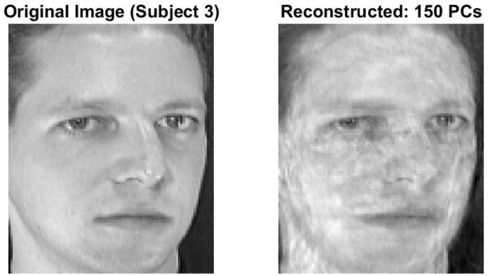




Differences between reconstructed and original images using 150 Eigenfaces





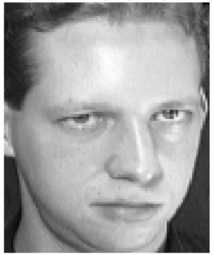


Differences between reconstructed and original images using 200 Eigenfaces

Original Image (Subject 1)

Reconstructed: 200 PCs

Original Image (Subject 2)

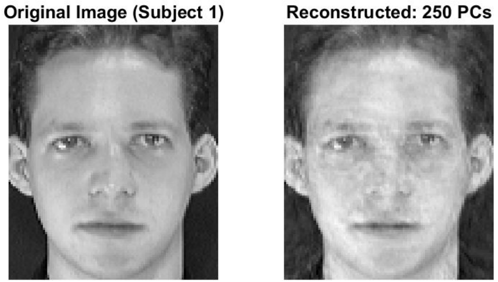


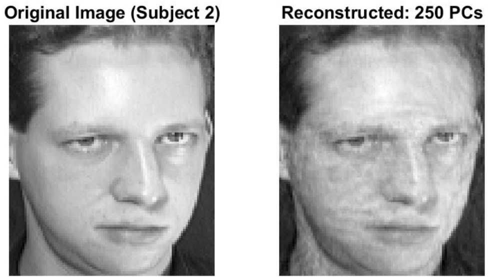
Reconstructed: 200 PCs

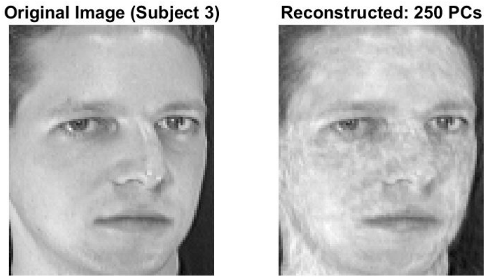
Original Image (Subject 3)

Reconstructed: 200 PCs

Differences between reconstructed and original images using 250 Eigenfaces



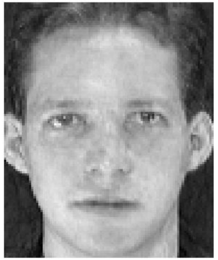




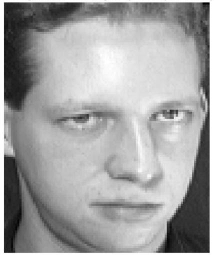
Differences between reconstructed and original images using 300 Eigenfaces

Original Image (Subject 1)

Reconstructed: 300 PCs



Original Image (Subject 2)



Reconstructed: 300 PCs

Original Image (Subject 3)

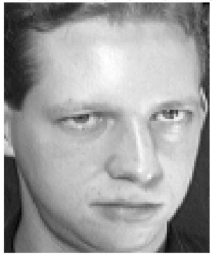
Reconstructed: 300 PCs

Differences between reconstructed and original images using 350 Eigenfaces

Original Image (Subject 1)

Reconstructed: 350 PCs

Original Image (Subject 2)

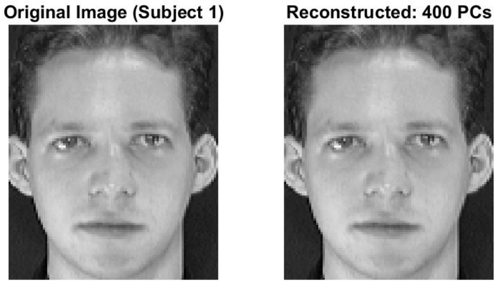


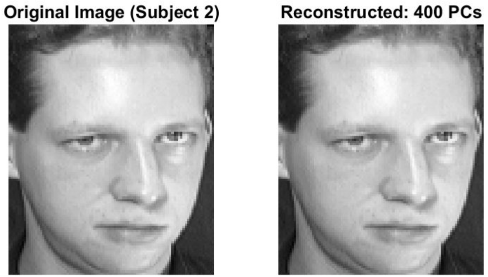
Reconstructed: 350 PCs

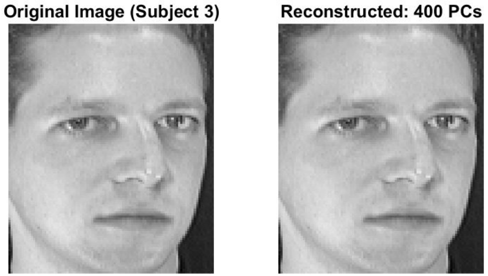
Original Image (Subject 3)

Reconstructed: 350 PCs

Differences between reconstructed and original images using 400 Eigenfaces



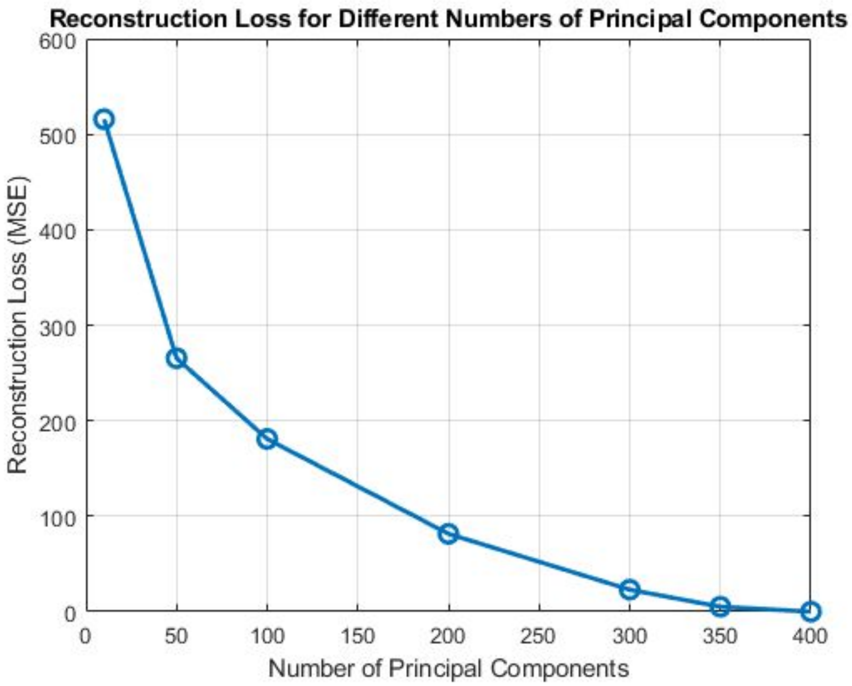




Number of eigenfaces required for reconstruction

Reasonable Error was defined by visual observation and Mean Squared Error (MSE):

- 350 Eigenfaces required
- MSE of 5.14



Classification (Face recognition and identification)

Training Data: Only face images.

Test Data: 120 face images, 30 non-face images.

Challenge: No exposure to non-face images during training.

PCA for Feature Extraction

- PCA calculated on training (face) images.
- Test data projected into PCA space.
- Normalization applied using training data parameters.

Explored Classification Methods

- **Linear Regression (LR)**: Misclassified non-face images.
- **KNN**: Distance-based thresholding.
- **K-means**: Two cluster separation.

KNN: Distance-Based Thresholding

Measured **distance to nearest neighbor** in PCA space.

Applied a threshold derived from validation data.

If distance > threshold → **Non-Face**.

K-means: Unsupervised Clustering

- Clusters: 2 (face and non-face).
- Test images assigned to clusters.
- Perfect separation achieved.

Key Takeaways

- **KNN**: Threshold-based distance → perfect classification.
- **K-means**: Unsupervised clustering → perfect separation.
- PCA transformation created distinct face/non-face separation.

Conclusion

- PCA and Reconstruction Quality

  Increasing the number of **principal components** improves reconstruction quality.

  Cumulative variance and **reconstruction loss** confirm this behavior

- **PCA Reduces Dimensionality Effectively**

  Original dimension: **10,304**.

  Reduced to **350–400 dimensions**.

  Top components capture the majority of variance.

  At **350 dimensions**: **MSE is extremely low**.

  At **400 dimensions**: **Reconstruction loss is effectively zero**.

Conclusion

- Eigenfaces as Features
  - **Eigenfaces** represent fundamental facial features:
    - Chin, mouth, nose, ears, hair, etc.
  - Faces are expressed as a **linear combination of eigenfaces**.
  - **More components → More detailed reconstructions**.

- **Visual Representation - Eigenfaces and Reconstructions**

  Include visual examples:

  - Original face images.
  - Reconstructions at 50, 100, 200, 350, and 400 components.
  - Show cumulative variance graph.

Takeaways

1. PCA reduces high-dimensional data efficiently.
2. **Eigenfaces** capture the most important facial features.
3. **350–400 components** → high-quality reconstructions.
4. PCA achieves dimensionality reduction with **minimal loss**.

Thank you & Questions