Comprehensive Analysis of Linear and Non-Linear Dimensionality Reduction for Face Recognition and Verification

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Academic Year 2025 – 2026

Project Idea

The main goal of this project is to apply **Singular Value Decomposition (SVD)** to the **Face Recognition** problem, in order to perform dimensionality reduction and extract the most informative features from facial images for **Principal Component Analysis (PCA)**. Furthermore, a comparison between PCA and non-linear dimensionality reduction via **Autoencoders** will be performed to evaluate linear versus non-linear feature extraction methods.

The project also incorporates **Face Verification**, employing similarity metrics such as **Cosine Similarity**, to extend recognition capabilities to practical security applications, such as the identification of suspicious individuals or granting system access through face-based authentication. In these scenarios, dimensionality reduction facilitates deployment on **embedded systems or camera devices**, enabling faster and lighter models suitable for **real-time inference**.

A supervised **SVM classifier** will be trained on features obtained from both PCA and Autoencoder, and standard classification metrics, including **Accuracy, Precision, Recall, F1-score, ROC curve, and AUC**, will be computed.

Comparative and Ablation Study

To further in-depth analysis, the project will include ablations and comparative experiments, including:

- **Evaluation metrics:** comparison of classification metrics before and after applying dimensionality reduction.
- **Number of PCA components:** evaluation of explained variance and impact on classification performance.
- **Classifier:** SVM (convex, non-gradient-based) vs a simple Neural Network (non-convex, gradient-based).

- **Similarity metric:** Cosine vs Euclidean distance for verification.

Steps in Python

1. Research and study of the state-of-the-art and underlying theory.
2. Select a labeled face dataset.
3. Explore the dataset and compute descriptive statistics.
4. Preprocess images.
5. Apply PCA via SVD and analyze variance explained.
6. Apply Autoencoder for non-linear feature extraction.
7. Train SVM and a simple Neural Network on PCA and Autoencoder features with K-Fold Cross Validation and Grid Search.
8. Compute classification metrics.
9. Apply Cosine and Euclidean Similarity for Face Verification.
10. Perform ablations and comparative experiments.
11. Display plots, eigenfaces and Autoencoder features for visual inspection.
12. Save trained models.
13. Demonstrate predictions on new/unseen images.
14. Create PowerPoint presentation.