Image Classification Using Wavelet Transform and Machine Learning

[Company name] | [Company address]

A self-driven project exploring feature extraction, decomposition techniques, and classification

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# INTRODUCTION

This project is my first hands-on exploration into **image-based machine learning** and facial recognition. I built it purely as a hobby project, motivated by my deep interest in machine learning and my desire to strengthen my skills in **Python, R, and other programming languages and analytical tools.**

Having already completed two structured projects under an internship program, I wanted to try something independent that would challenge me in new ways. This became my first time working with **image data** directly, and it opened up a whole new perspective for me.

In this project, I created a **celebrity face recognition pipeline** to identify **Gigi Hadid, Bella Hadid and Kendall Jenner** from photographs. Along the way, I explored and implemented several important concepts in computer vision and machine learning:

* **Face detection with Haar cascades** for extracting regions of interest.
* **Wavelet decomposition (2D DWT)** to highlight textures and edges, and to understand how different wavelet families affect image representation.
* **Feature engineering** by combining raw pixel data with wavelet-transformed features.
* **Classical machine learning models** including **SVM, Random Forest, Logistic Regression, and KNN**, evaluated with cross-validation and hyperparameter tuning.
* **Model selection and evaluation** with confusion matrices, classification reports, and performance metrics (accuracy, F1-score).

What began as a hobby project turned into a highly educational experience. It gave me confidence in handling datasets, applying transformations, building pipelines, and understanding how algorithms behave with real-world image data. I especially enjoyed diving deep into concepts like **wavelet transforms**, **Haar cascades**, and **dimensionality reduction with PCA**.

Although the project is relatively simple, I believe it reflects my curiosity and growing passion for **machine learning applied to images**. It was not only about building a working system but also about understanding the theory behind each step. This project is a stepping stone for me as I move towards tackling more advanced research problems in imaging, signal processing, and high-dimensional data analysis.

# Methodology

The project follows a complete machine learning pipeline for image-based classification, starting from raw image collection to model evaluation.

1. **Dataset Preparation**
   * A custom dataset of celebrity images (Gigi Hadid, Bella Hadid, Kendall Jenner) was collected.
   * Images were organized into folders per celebrity for easier labeling.
2. **Face Detection & Cropping**
   * Faces were detected using **Haar Cascade Classifiers** (frontal face + eyes).
   * Only regions with valid face + two eyes were cropped and saved.
   * This ensured that irrelevant background or incomplete detections were excluded.
3. **Feature Extraction**  
   Two complementary feature sets were engineered for each cropped face:
   * **Raw pixel features:** Each face was resized to **32×32**, then flattened into a vector.
   * **Wavelet features:** A **2D Discrete Wavelet Transform (DWT)** was applied (using Haar and Daubechies wavelets). Approximation coefficients were suppressed while detail coefficients were emphasized to capture **edges and textures**. The wavelet-transformed image was resized and flattened.
   * Both feature sets were concatenated into a single **high-dimensional feature vector**.
4. **Feature Scaling & Dimensionality Reduction**
   * Standardization was applied to normalize feature scales.
   * **Principal Component Analysis (PCA)** was used to reduce dimensionality while preserving most of the variance (90–99%). This step helped control overfitting and computational cost.
5. **Model Training & Hyperparameter Tuning**  
   Several machine learning models were tested:
   * **Support Vector Machines (SVM)** with linear and RBF kernels
   * **Random Forest Classifier**
   * **Logistic Regression**
   * **K-Nearest Neighbors (KNN)**
   * Each model was trained in a **pipeline** (scaling + PCA + classifier).
   * **GridSearchCV with Stratified K-Folds cross-validation** was used to optimize hyperparameters.
6. **Model Evaluation**
   * Models were compared using metrics: **accuracy, F1-score, and cross-validation mean score**.
   * Confusion matrices were plotted to visualize misclassifications.
   * The best-performing model was **SVM with Linear Kernel**.
7. **Prediction on New Images**
   * A preprocessing function was created to detect, crop, and transform new test images.
   * The trained SVM model was then used to predict whether the face belonged to **Gigi, Kendall or Bella**.

# Result

Working on this project was not just about building a face recognition system, but also about deepening my understanding of machine learning concepts and programming skills. Since it was my first time working with **images**, I became aware of how rich and complex image data actually is. I learned that images can be decomposed into **different frequency bands** using wavelet transforms, where the **low-frequency components** capture coarse structures and the **high-frequency components** preserve textures and edges. Exploring **multilevel decomposition** helped me understand how features can be extracted at different resolutions.

On the programming side, I learned to write more **robust code** by using **try-except blocks** for handling errors like missing images, which was new to me. I also improved my understanding of **data structures and algorithms (DSA)** while managing datasets, preprocessing steps, and model pipelines efficiently. Applying the **Discrete Wavelet Transform (DWT)**, experimenting with **Haar cascades** for face detection, and using classical ML models gave me confidence in working with both mathematical concepts and real-world implementations.

Overall, this project strengthened my foundation in **feature engineering, image preprocessing, and classical machine learning models**. It also made me more comfortable in thinking about the “pipeline approach” to problem-solving — from data collection to final deployment. Most importantly, it sparked my curiosity further and convinced me that I truly enjoy working with **machine learning and image analysis**.

# Conclusion

This project gave me my first real exposure to image-based machine learning, where I explored face detection, wavelet decomposition, feature extraction, and classical ML models. Beyond the technical aspects, it helped me build confidence in structuring a complete pipeline and handling challenges along the way. The experience confirmed my strong interest in **image analysis and high-dimensional data**, and it motivates me to continue developing these skills including those in areas such as medical imaging and brain data analysis.