Face Recognition Models and Facial Expression Analysis System

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1 Introduction

Face recognition and facial expression analysis have become critical components of modern artificial intelligence applications. This report outlines a unified system that first recognizes an individual using advanced face recognition technologies and then analyzes their facial expressions to infer emotional states. The system is further enhanced by the International Affective Picture System (IAPS) to validate emotional responses.

2 Face Detection and Recognition

2.1 Face Detection

Detecting a face in an image is the first step. Several advanced algorithms can be used:

- **Haar Cascade**: is an older technique for face detection, known for being fast but less accurate. This method uses Haar features (special features that analyze contrast differences in an image) to build classifiers for detecting faces. It generally requires less computational power and, therefore, can be faster, making it suitable for devices with lower processing capabilities. However, Haar cascades have several limitations:
  - It struggles with detecting faces at different angles or in varying lighting conditions.
  - False positives (non-face areas being recognized as faces) are more common.
  - It provides lower detection accuracy compared to modern deep learning models.

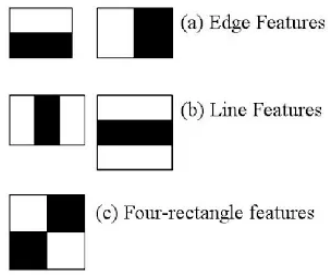

Figure 1: The first step in Haar feature extraction is calculating the differences in pixel intensities between adjacent rectangular regions in a detection window.

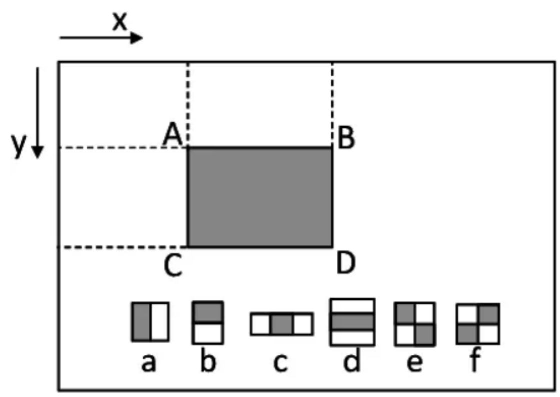

Figure 2: Without delving too much into the mathematics, integral images accelerate the computation of Haar features by creating sub-rectangles and reference arrays for each, which are then used to calculate the features.

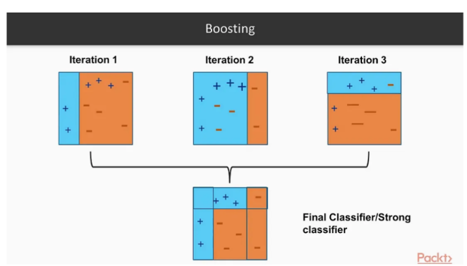

Figure 3: After that, Haar features are used with AdaBoost, a machine learning algorithm, to select the most relevant features and create a strong classifier by combining weak classifiers trained on those selected features.

- **Deep Learning-Based DNN Models (Modern Method)** DNN-based models achieve much more precise and accurate results by using deep neural networks. These methods typically require more computational power because they are more complex and computationally intensive.
  - YuNet is one of OpenCV's latest face detection models and is a high-performance, deep learning-based model. YuNet allows for accurate face detection regardless of variations in face orientation, lighting conditions, or other factors.
  - Learning Process: Deep learning models like YuNet learn faces in a more intricate manner during training, providing higher accuracy.
  - These models generally result in more precise detections with lower false positive rates.

DNN-based Face Recognition Models

[**1**]

- **VGG-Face**[**2**]: A deep convolutional neural network model based on the VGG architecture, achieving 97.78% accuracy on the LFW dataset. It is used for face recognition with high accuracy.
  How to use: The DeepFace library uses VGG-Face as the default model.
- **Google FaceNet**[**3**]: A state-of-the-art deep learning model by Google, used for face recognition, verification, and clustering. It achieves 99.63% accuracy on the LFW dataset and 95.12% on the YouTube Faces DB.
  How to use: Easily used via the DeepFace library with simple function arguments.
- **OpenFace**[**4**]: A lightweight deep learning model inspired by FaceNet, achieving 93.80% accuracy on the LFW dataset.
  How to use: OpenFace is available through the DeepFace library.
- **Facebook DeepFace**[**5**]: A deep neural network-based model developed by Facebook, achieving 97.35% accuracy on the LFW dataset.
  How to use: Available via the DeepFace library, similar to the Facebook DeepFace model.
- **DeepID**[**6**]: A deep learning-based face verification algorithm that surpasses human performance, achieving 99.15% on the LFW dataset.
  How to use: DeepID is accessible as one of the external models in the DeepFace library.
- **ArcFace**[**7**]: A cutting-edge model by Imperial College London and InsightFace, with 99.40% accuracy on the LFW dataset.
  How to use: ArcFace is available through the DeepFace library.

3 Facial Expression Analysis

[8] After recognizing a person, the next step is to analyze their facial expressions to determine emotional states.

3.1 Feature Extraction

Facial expressions can be analyzed using:

- **Geometric Feature-Based Analysis**: Measures movement in facial components such as eyebrows, eyes, and mouth.
- **Deep Learning Models**: CNNs and RNNs learn complex patterns in facial movements.

3.2 Emotion Classification

Once features are extracted, emotions are classified into categories such as happiness, sadness, anger, surprise, and fear. Models used for this step include:

- **DeepFaceEmotion (Keras-based)**
- **FER2013 (Trained on large emotion datasets)**
- **OpenFace (Open-source facial behavior analysis)**

4 Affect Recognition with IAPS

[9] To validate emotional responses, the system incorporates the International Affective Picture System (IAPS). This database provides standardized images with known valence and arousal ratings.

- If a person views an IAPS image labeled as high valence and arousal, the system expects a positive emotional response (e.g., happiness).
- If the detected facial expression does not match the expected response, it suggests emotional suppression or an alternative interpretation of the stimulus.

5 Applications

This integrated system has diverse applications:

- **Security and Surveillance**: Detecting stress or deception in high-security environments.
- **Affective Computing**: Enhancing human-computer interaction by adapting systems to users' emotions.
- **Marketing and UX Research**: Understanding consumer responses to advertisements and digital interfaces.

6 References

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