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Project Report: Face Liveness Detection

1. Introduction

1.1 Problem Statement

Face liveness detection aims to determine whether a face in a video stream is from a live person or a spoofed attempt (e.g., printed photo or digital screen). This is crucial in various security applications, including biometric authentication systems, to ensure that only real users are authenticated.

1.2 Objective

The goal of this project is to implement a real-time face liveness detection system that:

- Detects the presence of a face in a video frame.
- Analyzes blink patterns and subtle head movements to identify natural behaviors typical of a live face.
- Classifies the face as “live” or “spoof” based on these behavioral indicators.

2. Methodology

2.1 Project Architecture

The face liveness detection system is divided into three key stages:

1. **Frame Capture**: Captures frames from the user’s camera in real-time.
2. **Face and Feature Detection**: Detects and tracks facial features such as eyes and landmarks for blink detection and head movement analysis.
3. **Liveness Classification**: Uses blink detection and head movement metrics to classify the face as live or spoofed.

2.2 Key Detection Techniques

1. **Blink Detection**: Blinking is monitored by calculating the Eye Aspect Ratio (EAR) from eye landmarks. Consistent blinking indicates a live person.
2. **Head Movement Detection**: Slight, natural head movements are tracked by measuring the displacement of facial landmarks over consecutive frames. A lack of movement suggests the face may be a spoof.

3. Data Pipeline

3.1 Frame Capture

The OpenCV library is used to capture real-time video frames from the user’s camera, resized to a smaller window size (400x400 pixels) for focused liveness detection.

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3.2 Circular Mask and Face Placement Guide

To encourage users to align their face within a defined region:

- A circular mask is applied to display only the center of the camera feed, guiding users to position their face within the circle.
- A green circular outline is displayed for alignment, making the detection process more accurate and restricted to this area.

3.3 Preprocessing

Frames are converted to grayscale to improve detection speed, and eye and facial landmark coordinates are extracted for EAR and head movement analysis.

4. Detailed Implementation

4.1 Blink Detection

Blink detection is implemented using the **Eye Aspect Ratio (EAR)**, calculated from six eye landmarks.

- **Steps**:
  - The Euclidean distance between specific points around each eye is calculated to determine EAR.
  - If the EAR falls below a threshold for a set number of frames, a blink is counted.
- **Parameters**:
  - `EAR_THRESHOLD`: Determines when eyes are considered closed.
  - `CONSEC_FRAMES`: Minimum frames for which EAR must stay low to count as a blink.

4.2 Head Movement Detection

Head movement is measured by calculating the **displacement** of facial landmarks over frames.

- **Steps**:
  - Facial landmarks are detected for each frame.
  - Euclidean distances between corresponding landmarks in consecutive frames are calculated and summed to capture subtle head movements.
- **Output**:
  - A cumulative displacement value, where higher values indicate movement and therefore support liveness.

4.3 Liveness Classification

The system classifies the face based on both blink count and total head movement.

- **Thresholds**:

- Blink Count: At least two blinks indicate liveness.
- **Head Movement**: A minimum displacement threshold, e.g., `100`, is used to detect subtle, natural head movement.

If both thresholds are met, the face is classified as “live”; otherwise, it is considered a spoof.

5. Results and Performance Assessment

5.1 Performance Metrics

The model was tested in different lighting conditions and camera angles. Key metrics include:

- **Blink Detection Accuracy**: EAR thresholds and frame requirements were adjusted for accurate detection without frequent false positives.
- **Head Movement Sensitivity**: The cumulative displacement threshold for head movement was tuned to balance between detecting natural head motion and avoiding spoof classification errors.

5.2 Challenges and Limitations

- **Lighting Conditions**: Bright or low lighting impacts facial landmark detection accuracy. Adjustments were made to threshold values based on testing across different lighting setups.
- **Camera Quality**: Lower resolution or slower frame rates can impact blink and movement detection accuracy.
- **User Cooperation**: Users are required to align their face within the circular guideline, which might require cooperation for optimal results.

6. Conclusion

This face liveness detection project demonstrates the effectiveness of combining blink and head movement detection to verify live faces. The circular camera setup enhances usability by focusing the detection region, and combining multiple indicators improves robustness against spoofing. With potential applications in biometric authentication systems, the project contributes toward enhancing security in face-based authentication systems.

7. Future Improvements

- **Depth Analysis**: Adding depth analysis using stereo vision or optical flow to increase spoof detection accuracy.
- **Improved Facial Landmark Tracking**: Using advanced, deep learning-based facial landmark detectors could enhance accuracy.
- **Additional Behavioral Biometrics**: Including features like mouth movement or speech analysis could further strengthen liveness detection.