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The objective of this project was to accurately identify and detect the circular boundaries of the pupil and iris through a series of eye images. The approach I used for this assignment involved preprocessing each image, enhancing the contrast, applying edge detection, and then using Hough Transform to identify the circle shapes in relation to the pupil and iris.

Approach and Algorithms Used:

1. **Preprocessing and Contrast Enhancement**:
    - Contrast Limited Adaptive Histogram Equalization (CLAHE) was used to enhance the contrast in each image, which made the pupil and iris edges more recognizable.
2. **Edge Detection**:
    - The edge maps were created separately for the pupil and iris. For the pupil, thresholding and morphological closing were applied to reduce noise and increase the edge connectivity.
    - For the iris, a masked edge map was created by applying a circular mask around the eye to limit the edge detection within just the iris region.
3. **Hough Circle Transform**:
    - The circular Hough Transform was used to detect the circular boundaries based on the edge maps.
    - There were separate Hough Circle detection steps applied for the pupil and iris. Parameters for minimum and maximum radius were adjusted based on the pupil size, which helped narrow the iris search within a reasonable range.

Challenges Faced and Solutions

1. **Distinguishing Pupil and Iris Boundaries**:
    - The clarity of the pupil boundary was often stronger than the iris boundary, which often appeared faint. This made it challenging to identify the iris edges accurately.
    - **Solution**: Different contrast enhancement levels were used for pupil and iris detection. The edge map for the iris was further adjusted by applying a Gaussian blur to reduce any noise and ensure only relevant edges were highlighted.
2. **Parameter Adjustments for Hough Circle Transform**:
    - Finding the correct parameters for the Hough Circle Transform was very important. Sensitivity, radius limits, and other parameters had to be adjusted to ensure accurate boundary detection.
    - **Solution**: For pupil detection, different values were experimented with param1 and param2 to make the detection stronger. For the iris, additional scoring criteria was introduced, such as avoiding circles that were off-center relative to the pupil, which improved the alignment.
3. **Center Alignment and Radius Consistency**:
    - In some images, the detected iris boundary was slightly off-center or larger than expected. This was challenging because of the different sizes of the iris and positions relative to the pupil.
    - **Solution**: A scoring system was implemented to analyze detected circles that were better aligned with the pupil's center and matched the expected iris radius more closely. The circle with the highest "score" was used in the final output.

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Insights and Observations

- **Effective Contrast Enhancement is Key**: CLAHE was very effective for both pupil and iris edge enhancement. Using these features helped in balancing contrast levels for detection.
- **Masked Edge Map for Iris Detection**: By using a mask centered around the pupil, the iris edge detection focused on the region of interest, reducing noise and improving the accuracy of Hough Circle detection for the iris.
- **Parameter Sensitivity in Hough Circle Transform**: Small adjustments and tweaks in the Hough parameters (especially minRadius, maxRadius, and param2) significantly affected the results, showing that each boundary detection problem may need unique parameter tuning.

Potential Improvements

- **Threshold Adjustment:** Instead of using a fixed threshold values for the pupil and iris, an improvement could be to dynamically set the threshold based on the image's brightness or contrast level. This approach can help improve detection consistency across images with varying lighting conditions.
- **Use of Median Blurring for Noise Reduction:** Adding a median blur step before edge detection could be an improvement as it is effective at reducing noise while preserving edges, which can improve the accuracy of the edge detector.

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References

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