Retinal Vessel Segmentation

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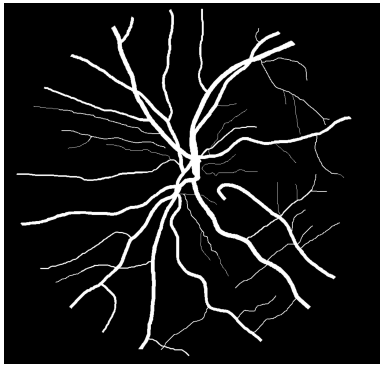
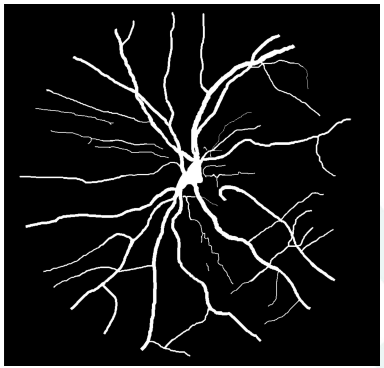
Dataset

- The **CHASEDB1** dataset comprises 28 retinal images, representing both eyes of 14 participants. (2,68,80,000 pixels)
- Each image is accompanied by two ground truth annotations ("1stHO" and "2ndHO") from different human observers,totaling 84 images.
- The file naming convention includes participant numbers (01-14), eye identifiers (L/R), and ground truth sources.

Retinal Image



1stHO



2ndHO

Problem Statement

- **Objective:** The main goal is to create a system that can accurately identify and segment blood vessels in images of the retina.
- This segmentation is crucial because analyzing retinal blood vessels helps in diagnosing and tracking the progression of eye diseases like diabetic retinopathy and glaucoma.
- By improving segmentation accuracy, doctors can detect issues early, which enables better treatment planning.
- **Challenges:** Identifying these vessels in retinal images is difficult because:
  - The blood vessels have low contrast compared to the rest of the retina.
  - The images can be noisy, with areas that are too bright or too dark.

EDA

- **Green Channel Isolation**:
  The green color channel is isolated from each image, as it provides better contrast between the blood vessels and the background compared to the red and blue channels.

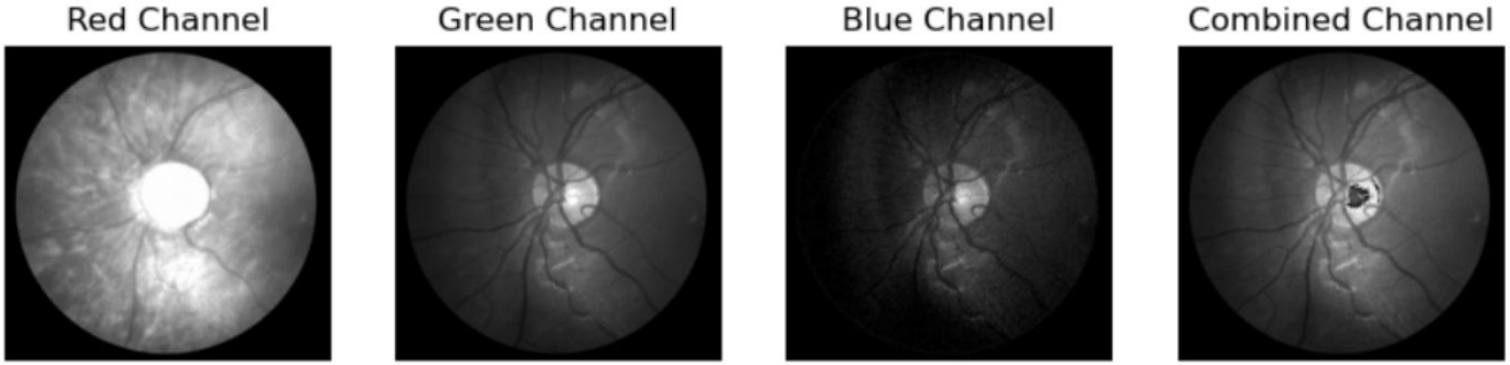
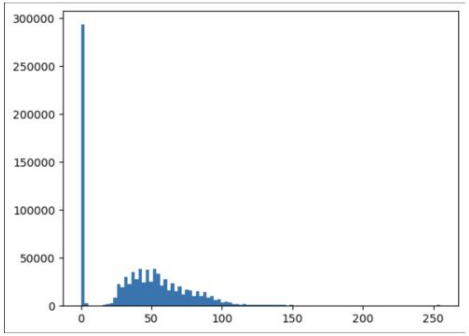


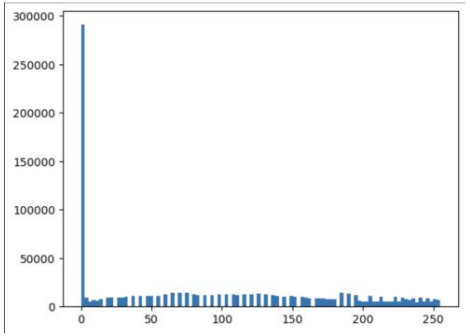
Figure 1: The different channel confirms our hypothesis that the green channel exhibits better contrast between the vessels and the background.

EDA

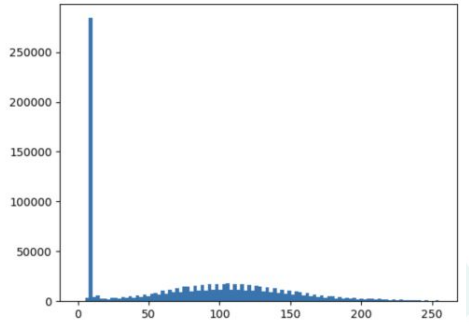
- Contrast Limited Adaptive Histogram Equalization (CLAHE):
  - **Purpose:** To improve the overall contrast in the retinal images without overly brightening certain areas.
  - **Process:** CLAHE applies localized contrast enhancement by adjusting the pixel intensities in smaller sections of the image and limiting amplification to avoid excessive brightness.
  - **Result:** This process helps to bring out finer details of the vessels, particularly in areas where the vessels may be faint due to low contrast.



(a) Histogram of Green Channel



(b) Equalized Green Channel



(c) CLAHE on Green Channel

Preprocessing

They are two pre-processing steps done on the retinal image with the final unsupervised thresholding to get segmented vessels.

- **Morphological Operations:** We have applied morphological opening and closing with noise erosion and dilation. These operation removes small noise or objects that don't fit the structuring element shape, smoothing the boundaries of vessels and helps close small holes or gaps in vessels while maintaining the overall shape.

- **Hessian Widening:** Hessian widening identifies and enhances elongated features (e.g., vessels or edges) in the image by analyzing the curvature information. It is used to enhance images by highlighting wide and thin vessels

The effect of the preprocessing is really evident in the pictures present in the codefile.

Hypothesis Testing

Null Hypothesis 1: Choosing the green channel for the image over the grayscale image does not improve contrast and visibility of retinal vessels, and segmentation accuracy remains unchanged.

Null Hypothesis 2: Applying CLAHE does not improve contrast and visibility of retinal vessels, and segmentation accuracy remains unchanged.

We will be conducting the following experiments to validate our hypothesis.

- **Experiment 1:** Perform segmentation on retinal images with green channel and grayscale image, measuring segmentation accuracy, structural similarity index (SSI), F1 score and peak signal-to-noise Ratio (PSNR) in both cases.
- **Experiment 2:** Perform segmentation on retinal images with and without CLAHE applied, measuring segmentation accuracy, structural similarity index, F1 score and peak signal-to-noise Ratio in both cases.

Experiment 1

We have a taken a subset of the dataset to experiment for our hypothesis. The flow of the operations are - Grayscale/Green Channel selection, CLAHE, Morphological Operations, Hessian Widening and then Thresholding.

Evaluation Metrics	Grayscale#1	Green Channel#1	Grayscale#2	Green Channel#2
Accuracy	0.898	0.9139	0.9139	0.925
SSIM	0.6945	0.7314	0.7384	0.7639
PSNR	9.6262	10.298	10.346	10.8388
F1	0.5164	0.5782	0.6084	0.6632

The green channel for both the images, shows superior segmentation results, with really good F1 scores. Hence allowing us to reject the null hypothesis 1.

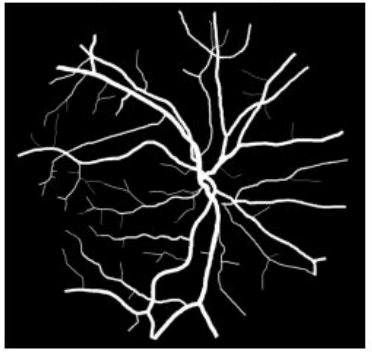
Experiment 1

One can clearly see choosing the green channel over the grayscale image reduces noise leading to better segmentation results and accuracy. This is also quite evident from slide 4 where we can visually also verify that green channel shows less noise in comparison to the grayscale.

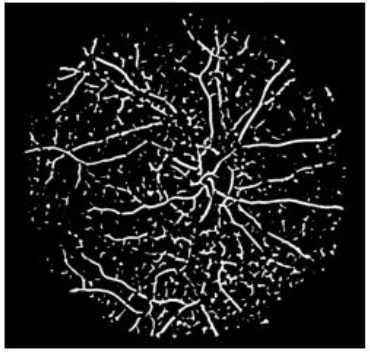
Image: Image_01R.jpg

Original Image

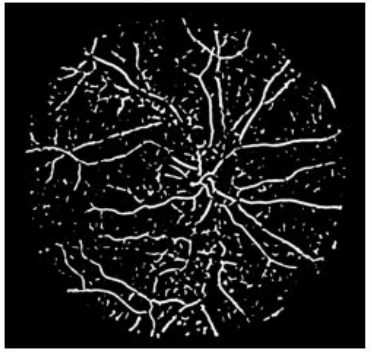
Segmented Image



Thresholding on Grayscale



Thresholding on Green Channel



Experiment 2

Segmentation results with and without applying CLAHE on the retinal images.

Evaluation Metrics	Without CLAHE#1	With CLAHE#1	Without CLAHE#2	With CLAHE#2
Accuracy	0.9288	0.9139	0.9346	0.925
SSIM	0.7901	0.7314	0.8096	0.7639
PSNR	11.3494	10.298	11.7395	10.8388
F1	0.6498	0.5782	0.7217	0.6632

Based on visual inspection, it showed CLAHE is able to improve the contrast of the vessels and the retinal background. But the results shows that the preprocessing steps and thresholding on images we have choses without CLAHE gives better segmentation results. Therefore we cannot reject our null hypothesis 2.

More detailed experiment is present in the codefile.

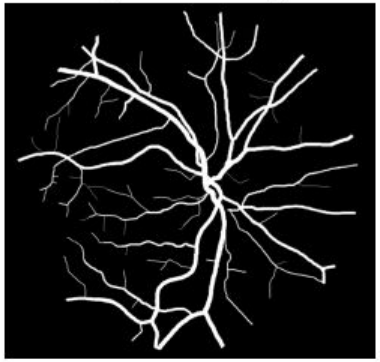
Experiment 2

Here we have kept the consistent green channel for both cases; with or without CLAHE. One can see without CLAHE we have less noise leading to better segmentation results and accuracy. This is actually a little contradictory to the visual inspection of the both images, and to the general convention followed for retinal vessel segmentation. One reason for this could be the preprocessing steps for supportive towards without CLAHE ones.

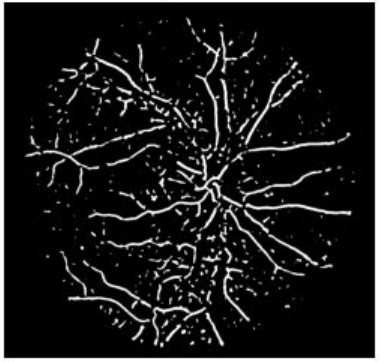
Image: Image_01R.jpg

Original Image

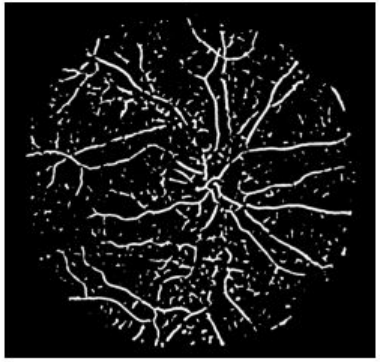
Segmented Image



Thresholding without CLAHE



Thresholding with CLAHE



Thank you