ELL715

Project Report (Group 9)

Vessel Enhancement

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1 Problem Statement

We are given retinal scanned images. We have to enhance the blood vessels present in the images of the eye, using image processing

1.1 Dataset

We use DRIVE dataset. It has two folders, `test` and `training`. Each folder contains sub-folders named `images`, `1st_manual`, `masks`.

1. `images` contains 20 fundus images which are considered input in all problems.
2. `1st_manual` contains the labelled fundus images corresponding to the original 'images', known as ground truths, which are the expected output of retinal vessel segmentation
3. `masks` are used to define the region of interest (ROI) and can be multiplied to the retinal images at any stage to get rid of unnecessary pixels.

1.2 Past Work

We find Sidra Aleem et Al's paper `Fast and Accurate Retinal Identification System: Using Retinal Blood Vasculature Landmarks`[2019] useful for our project. It discusses processing and matching of retinal images for a retinal identification system with Identification and Enrollment modules.

2 Method

We will approach the problem by first preprocessing the images, then enhancing using filters, and finally post-processing and evaluating the result.

2.1 Pre-Processing

2.1.1 Green Channel Extraction

We first pick the green channel from the image to get a better contrast as the retinal vessels are most visible in green channel. Green channel gives best separability of the vessels from the eye fluid

2.1.2 CLAHE Histogram Equalization

Contrast Limited Adaptive Histogram Equalization performs histogram equalization in small patches or small tiles with high accuracy and contrast limiting. The neighboring tiles are then combined using bilinear interpolation to remove the artificial boundaries. CLAHE limits contrast amplification to reduce noise amplification

2.1.3 OTSU Thresholding

We use OTSU threshold to find the boundary mask to remove small noise from black background. OTSU finds the globally optimal thresholding value then applies it to the image, giving best separation of 2 parts. The algorithm exhaustively searches for the threshold that minimizes the intra-class variance, defined as a weighted sum of variances of the two classes:

$\sigma_w^2(t) = \omega_0(t)\sigma_0^2(t) + \omega_1(t)\sigma_1^2(t)$

2.1.4 Morphological Transform

Image Opening (Erosion Followed by Dilution) opens the white area and closes the black vessels

2.1.5 Boundary Removal

To remove the outer circle from image, we take the circular disk mask then erode it with a **circular kernel**. Then mask the image with this eroded mask.

$\beta(A) = A - A \ominus B$

2.2 Vessel Enhancement

We use **Frangi filter** to enhance the image. Frangi filter measures how elongated an image region is, so it detects vessels as objects that are *"long"* and not *"blobby"*

2.3 Post-Processing

2.3.1 Multilevel OTSU Thresholding

In this multiple threshold levels are selected on histogram and group the pixels of an image into different regions to maximize the inter-class variance.

2.3.2 Wavelet-Based Segmentation

We use **bior1.3** wavelets to segment the image further.

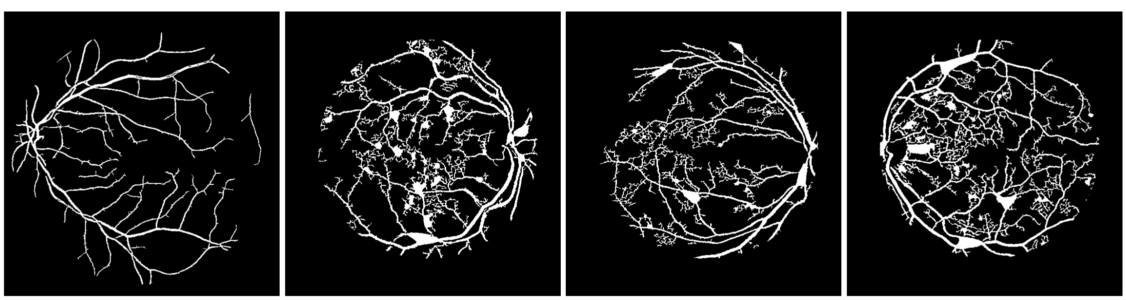
2.3.3 K-means Segmentation

Used to segment the interest area from the background. It clusters, or partitions the given data into K-clusters or parts based on the K-centroids. K=2 was chosen.

3 Results

We run the process on 20 images from the dataset, and report the results by checking if the pixels are matching or not in the output and the ground truth. We count the pixels and report in this table.

3.1 Sample Outputs



3.2 Numerical Analysis

Image #	True Positive	True Negative	False Positive	False Negative	Accuracy (%)	Sensitivity (%)	Specificity (%)
1	8857	295044	10258	15801	92.10	46.34	94.92
2	9954	290684	9467	19855	91.11	51.25	93.61
3	6940	287263	20974	14783	89.16	24.86	95.11
4	13602	281947	9784	24627	89.57	58.16	91.97
5	8926	292148	6143	22743	91.25	59.23	92.78
6	9731	292734	9653	17842	91.67	50.20	94.26
7	8886	289800	11087	20187	90.52	44.49	93.49
8	11065	286202	11530	21163	90.09	48.97	93.11
9	9586	292738	9471	18165	91.62	50.30	94.16
10	7004	294056	10020	18880	91.24	41.14	93.97
11	6042	300307	9755	13856	92.84	38.25	95.59
12	8706	292874	10102	18278	91.40	46.29	94.13
13	9233	293144	10130	17453	91.64	47.68	94.38
14	11065	286202	11530	21163	90.09	48.97	93.11
15	10076	288652	12696	18536	90.53	44.25	93.97
16	11519	282927	11149	24365	89.24	50.82	92.07
17	9876	288298	12821	18965	90.37	43.51	93.83
18	9431	289128	12355	19046	90.48	43.29	93.82
19	9608	289236	12376	18740	90.57	43.70	93.92
20	8179	292780	12179	16822	91.21	40.18	94.57
Average					**90.84**	**46.09**	**93.84**
Standard Deviation					**0.95**	**7.32**	**0.92**

The final Average accuracy is **90.84%**, sensitivity is **46.09%** and specificity is **93.84%**

4 Code and Images

We have attached the code as `code.ipynb` file and the output images as `results/` along with this report.