Enhancing Ocular Disease Diagnosis, blood vessel segmentation, and vessel diameter estimation using an advanced deep learning

CSE499B

Section: 23

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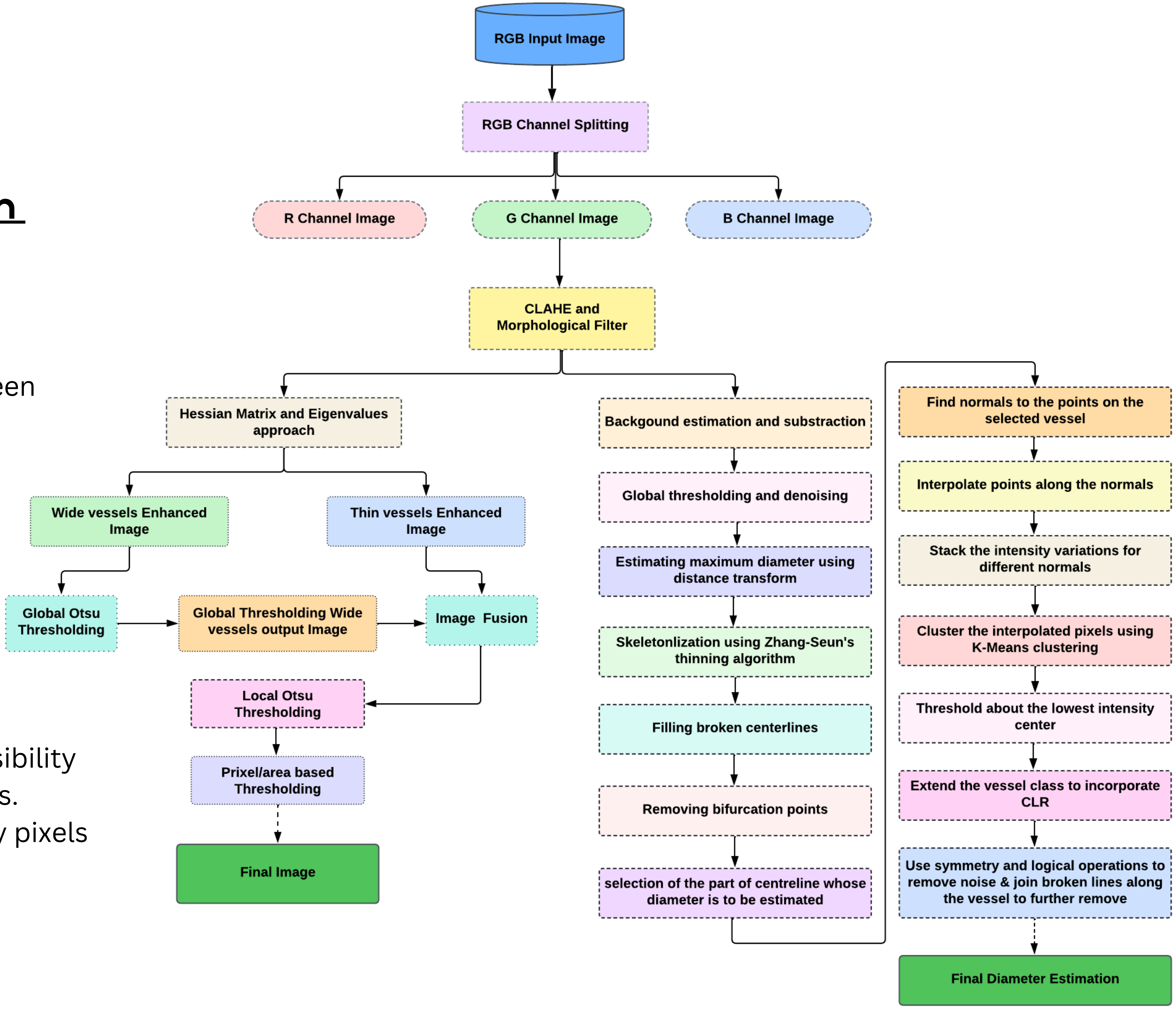
System Diagram

vessel segmentaion implementation

- **Colleting dataset :** Collected training images and corresponding segmented images.
- **RGB channel splitting:** Splitting into read, green and blue channel.
- **CLAHE and Morphological Filtration:** To to improve the contrast of images.
- **Hessian matrix and Eigenvalues approach:** produce improved images of wide and thin blood vessels
- **Image Fusion:** Combines global threshold thick vessel image with thin vessel enhanced image to create a fusion image.
- **Local Otsu Thresholding:** Increases vessel visibility while reducing noise and unnecessary objects.
- **Pixel/ area based Thresholding:** Removes any pixels below a threshold area (30px)
- **Final Output**



Vessel diameter estimation

1. Vessel Segmentation and Centreline Extraction

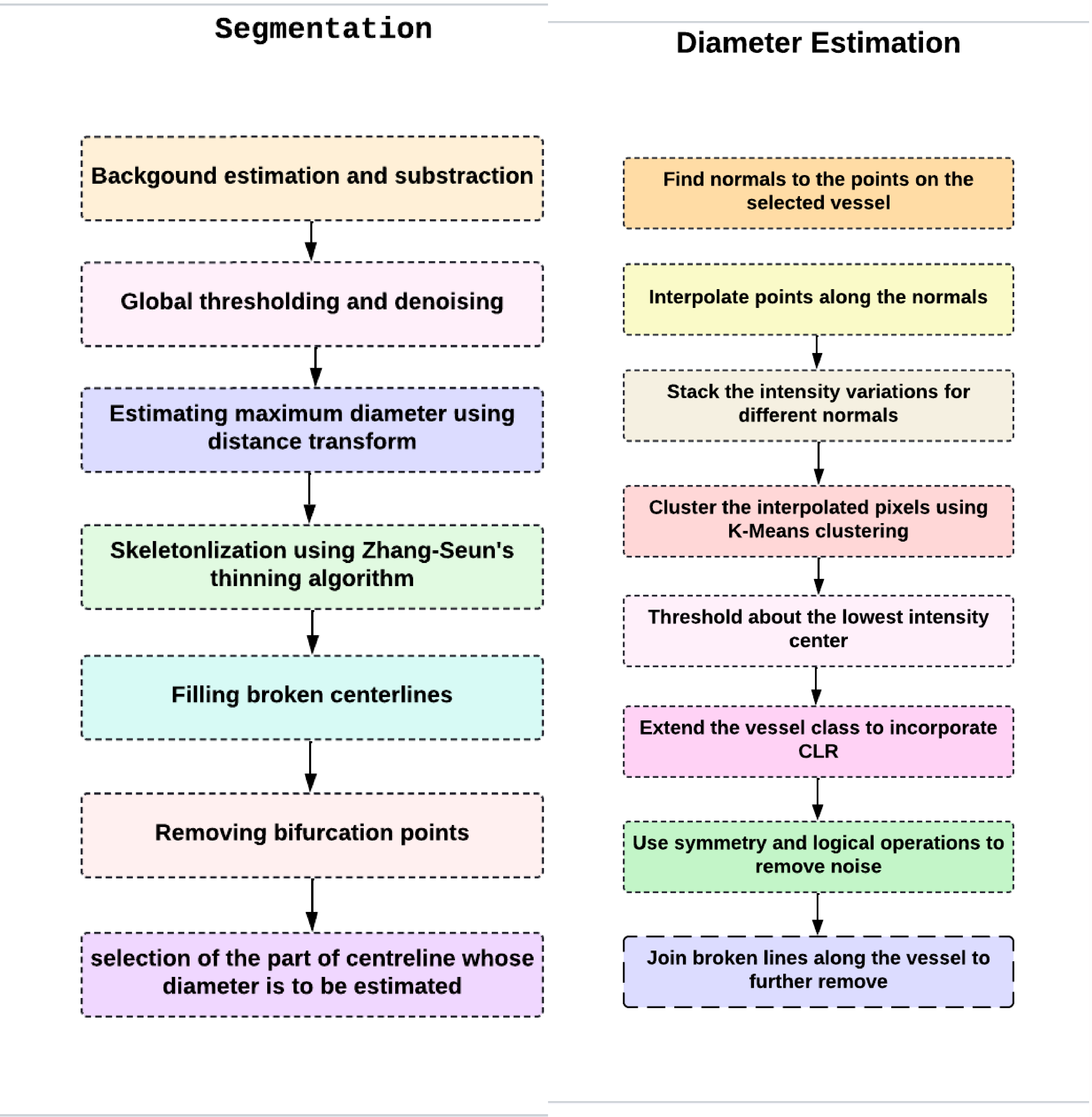
- **Background Subtraction:** Highlights vessels by removing background
- **Thresholding:** Converts image to binary map (vessels as dark pixels)
- **Noise Removal:** Eliminates small, isolated bright spots
- **Skeletonization:** Thins vessels to single-pixel lines and fills gaps

2. Interpolation Normal to Centrelines and Clustering

- **Normals Generation:** Draws perpendicular lines along centrelines
- **Intensity Mapping:** Creates a 3D map of intensity values along normals
- **Clustering:** Isolates vessel pixels based on intensity
- **CLR Handling:** Incorporates central light reflex using symmetry
- **Noise Reduction:** Fills breaks and joins segments for a refined vessel profile

Key Outputs

- **Enhanced Vessel Images**
- **Accurate Vessel Diameters**



Analysis of the Design

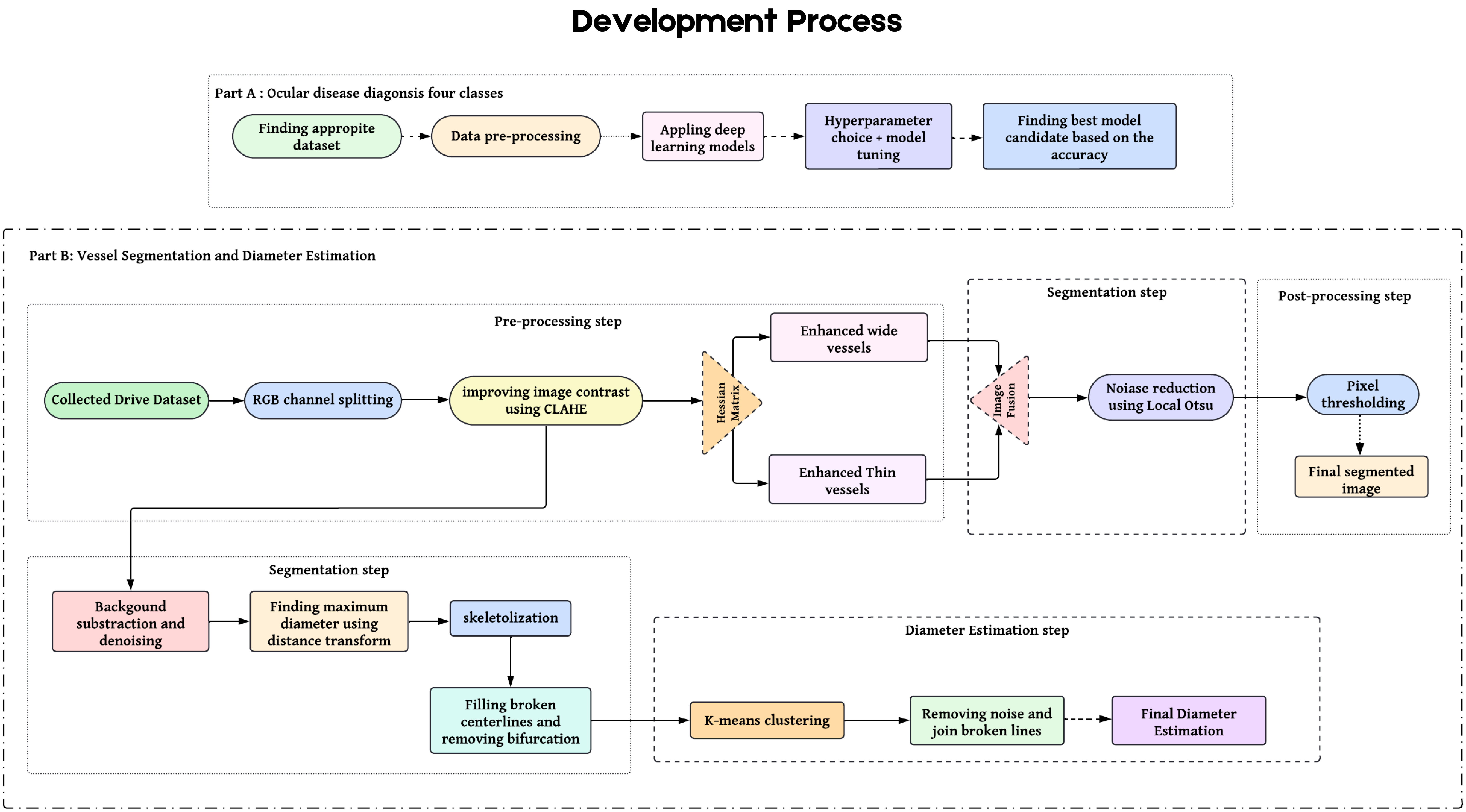
We mainly focused on two parts of this project: **blood vessel segmentation** and **vessel diameter estimation**

First part: Blood vessel segmentation from ocular images

Diagnosing eye diseases depends extensively on the appearance and structure of blood vessels in retinal images. We applied a less computational, ***unsupervised automated technique*** with promising results for detecting retinal vasculature using a morphological hessian-based approach and region-based Otsu thresholding. After blood vessel segmentation, the doctor can be able to identify abnormalities in the blood vessels of the eye, including **Glaucoma**, **age-related muscular degeneration (AMD)**, and **Hypertension(high blood pressure)**

Second part: Vessel's diameter estimation from ocular images

We needed to divide this part into ***vessel segmentation and centerline extraction***, as well as ***interpolation normal to the centerlines and clustering***. After going through this process, we can calculate vessel diameter (micrometer), which can be used to diagnose ocular and systemic vascular diseases, including **coronary heart diseases**, **ischemia**, and **diabetes mellitus**.

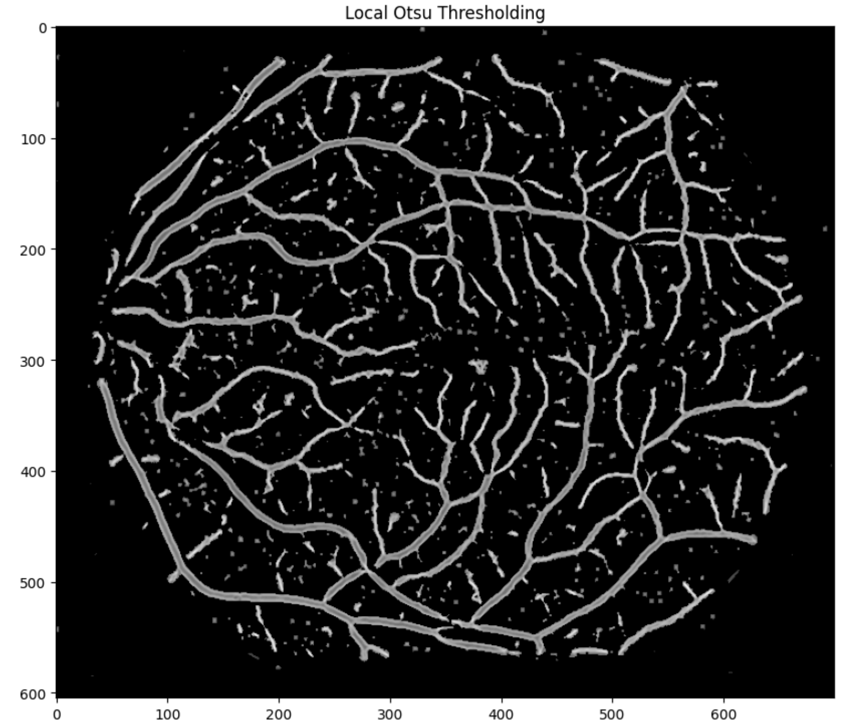


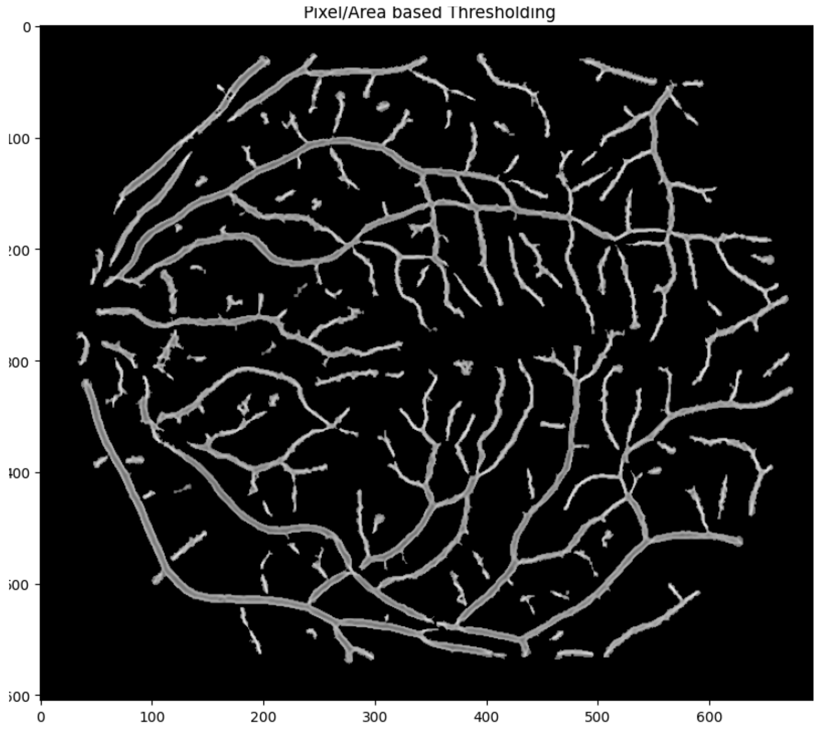
Development Process
Part A : Ocular disease diagonsis four classes
Finding appropite dataset
Data pre-processing
Appling deep learning models
Hyperparameter choice + model tuning
Finding best model candidate based on the accuracy
Part B: Vessel Segmentation and Diameter Estimation
Pre-processing step
Collected Drive Dataset
RGB channel splitting
improving image contrast using CLAHE
Hessian Matrix
Enhanced wide vessels
Enhanced Thin vessels
Segmentation step
Image Fusion
Noiase reduction using Local Otsu
Post-processing step
Pixel thresholding
Final segmented image
Segmentation step
Backgound substraction and denoising
Finding maximum diameter using distance transform
skeletolization
Filling broken centerlines and removing bifurcation
Diameter Estimation step
K-means clustering
Removing noise and join broken lines
Final Diameter Estimation

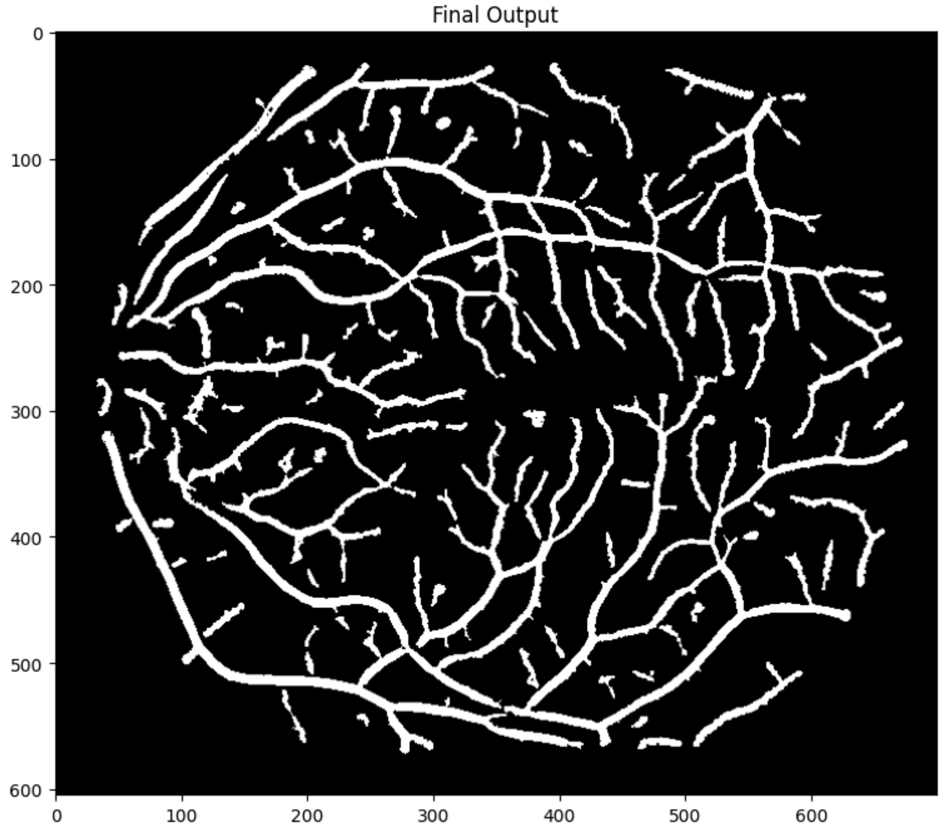
Result

Segmentation

Input Image





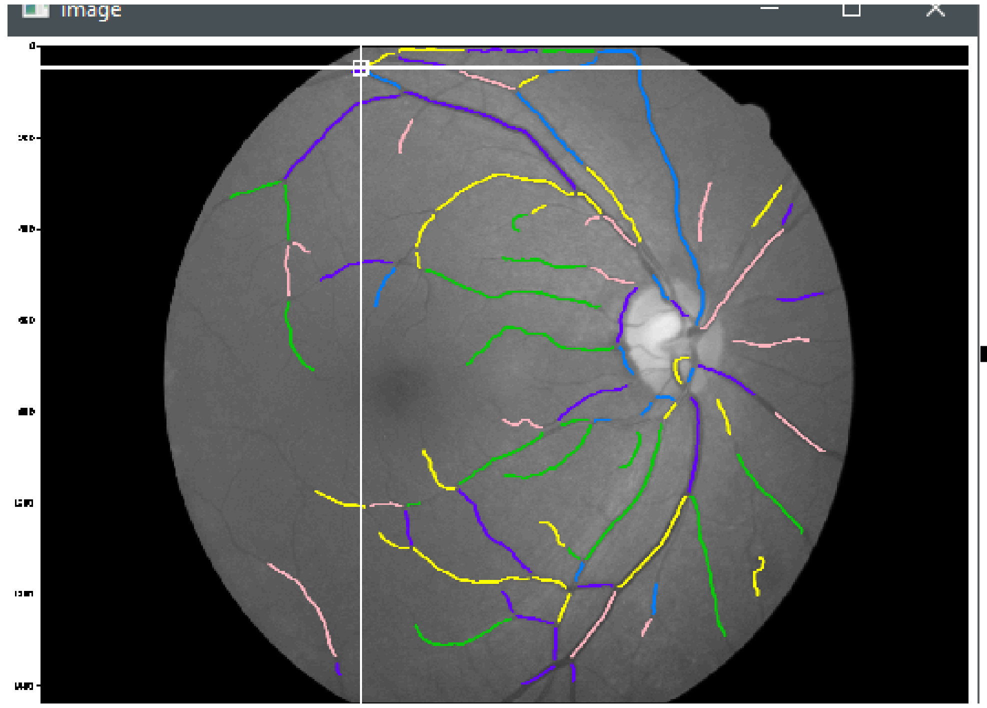


Output Image

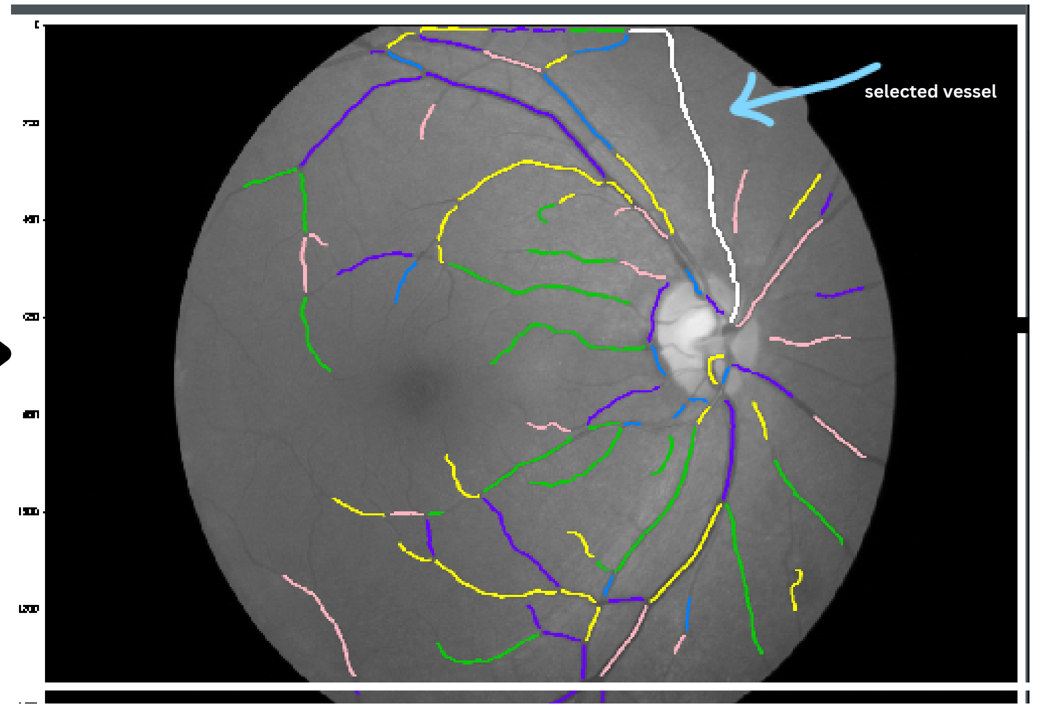
Image No.	DRIVE dataset		
	Accuracy	Sensitivity	Specificity
1	0.915	0.722	0.932
2	0.942	0.716	0.958
3	0.891	0.823	0.895
4	0.948	0.681	0.969
5	0.899	0.767	0.912
6	0.917	0.803	0.926
7	0.919	0.786	0.930
8	0.936	0.825	0.945
9	0.927	0.748	0.942
10	0.905	0.781	0.916

Result

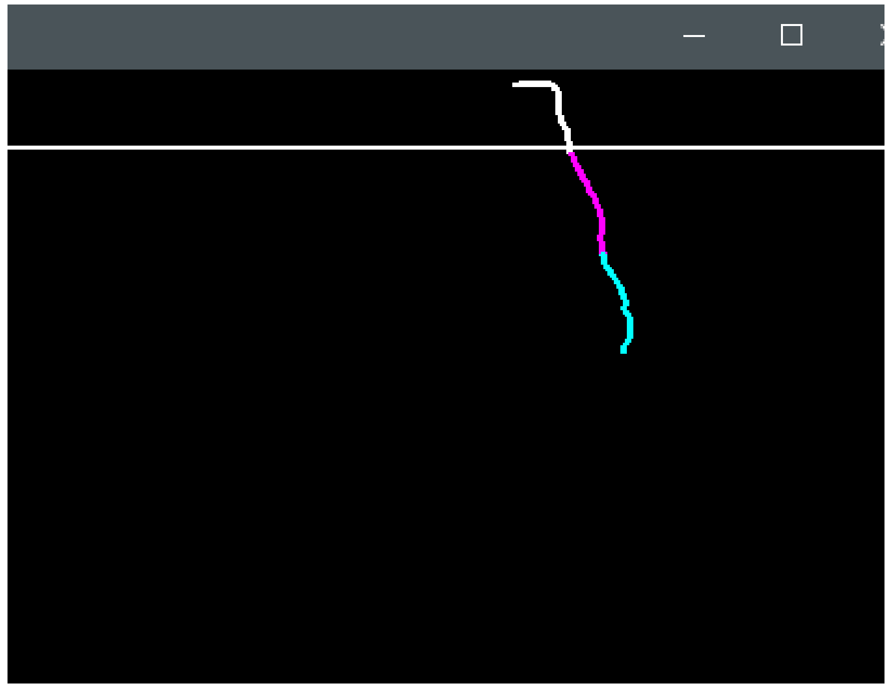
Diameter Estimation:



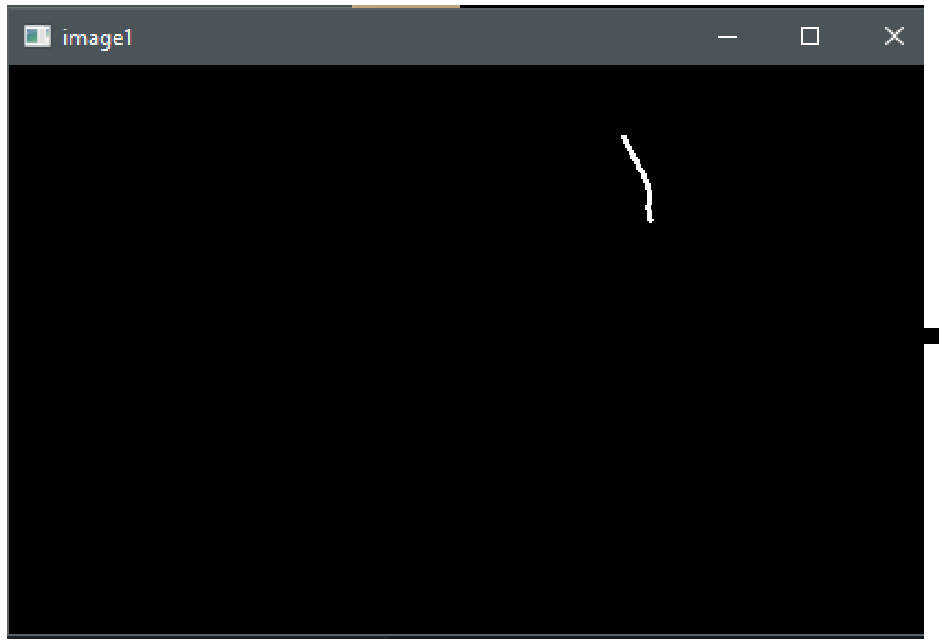
SIZE IS : (779, 1166, 3)
Maximum diameter: 20.5044002532959 at the point: (732, 348)



In how many parts you want to divide the selected vessel (Please enter an integer <=5): 3



selected vessels and splited into 3 parts



selected part(middle) of the vessel for diameter estimation

selected part showing in the original fundus image

Final Result

Average diameter length: 6.821138211382114
Median diameter length: 7.0
Standard deviation: 0.004640076349999139

Tools & Technologies

Tools	Function	Why we selected this tool
TensorFlow	Deep Learning Framwork	TensorFlow is strong, flexible, and supported by the community. It offers many resources and features for building and training neural networks
Keras	High-level API for TensorFlow	It makes it easier to build and train deep learning models
OpenCV	open-source computer vision and cross-platform	It offers a broad range of functions and methods for tasks like image enhancement, segmentation, feature extraction, and image processing, including edge detection, morphology, and feature identification
Numpy, Pandas	Numpy handles arrays and mathematical operations, while pandas deals with structured data manipulation	Data preparation and analysis in eye disease detection were made more accessible using Numpy and Pandas due to their effective data handling, numerical computing, and deep learning integration.
Matplotlib, Seaborn, and Scikit-learn	Matplotlib and Seaborn provides Data visualization for analysis and presentation then Scikit-learn offers deep-learning algorithms for disease diagnosis and segmentation	It provides Widely used and well-documented tools for visualization and deep learning tasks essential for ocular disease diagnosis projects
Google Collab Pro	Cloud-based Jupyter Notebook environment	It provides solid GPUs and TPUs, available with Google Collab Pro, which helps train deep-learning models

Usability and Manufacturability

Usability:

- Doctors can use segmented images for faster diagnosis of ocular diseases.
- Find abnormalities in segmented vessel images.
- Compare patent’s previous status with the present one, more faster and more accurately
- Vessel diameter estimation will enable doctors to find farther reasons of ocular diseases occurring due to other organ malfunctions.

Manufacturability:

Manufacturing or implementing a single software, website, or web app to perform disease diagnosis of cataracts, glaucoma, and diabetic retinopathy along with blood vessel segmentation and vessel diameter estimation will make easier and cost effective for doctors. Farther training it with high quality mobile image instead of images generated by ophthalmoscope will increase it’s usability and make it available for the mass.

Environment Considerations & Sustainability

Environment Consideration:

A deep learning, AI-based approach for detecting ocular diseases will significantly reduce the medical wastage required for diagnosis. Also, it won’t require any physical data, or patent records to be stored psychical, instead, it will be cloud-based. Which will significantly reduce carbon footprint.

We have chosen the best models with the highest accuracy and more optimized methods that require less computation power to reduce the carbon footprint generated from Hardware and storage wastage.

Sustainability:

The sustainability of healthcare depends on the active participation of all stakeholders, fostering a culture of feedback and collaboration. By continuously refining and improving systems based on real-world experiences, we can ensure that healthcare remains adaptable, efficient, and effective in meeting the needs of both providers and patients.