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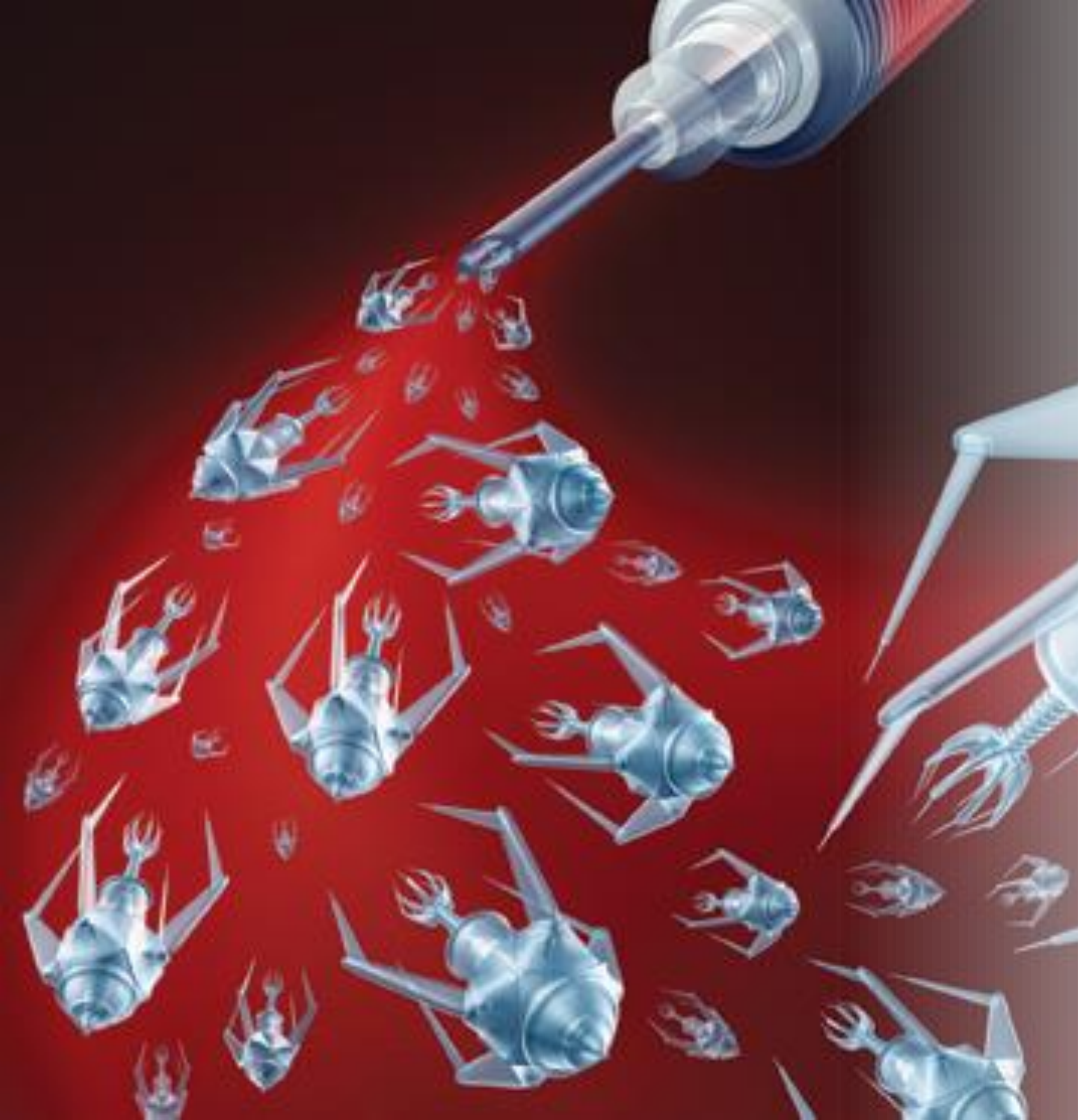
EE697 Medical Imaging Course Project

Optical Coherence Tomography (OCT) Image Processing for Eye Diseases

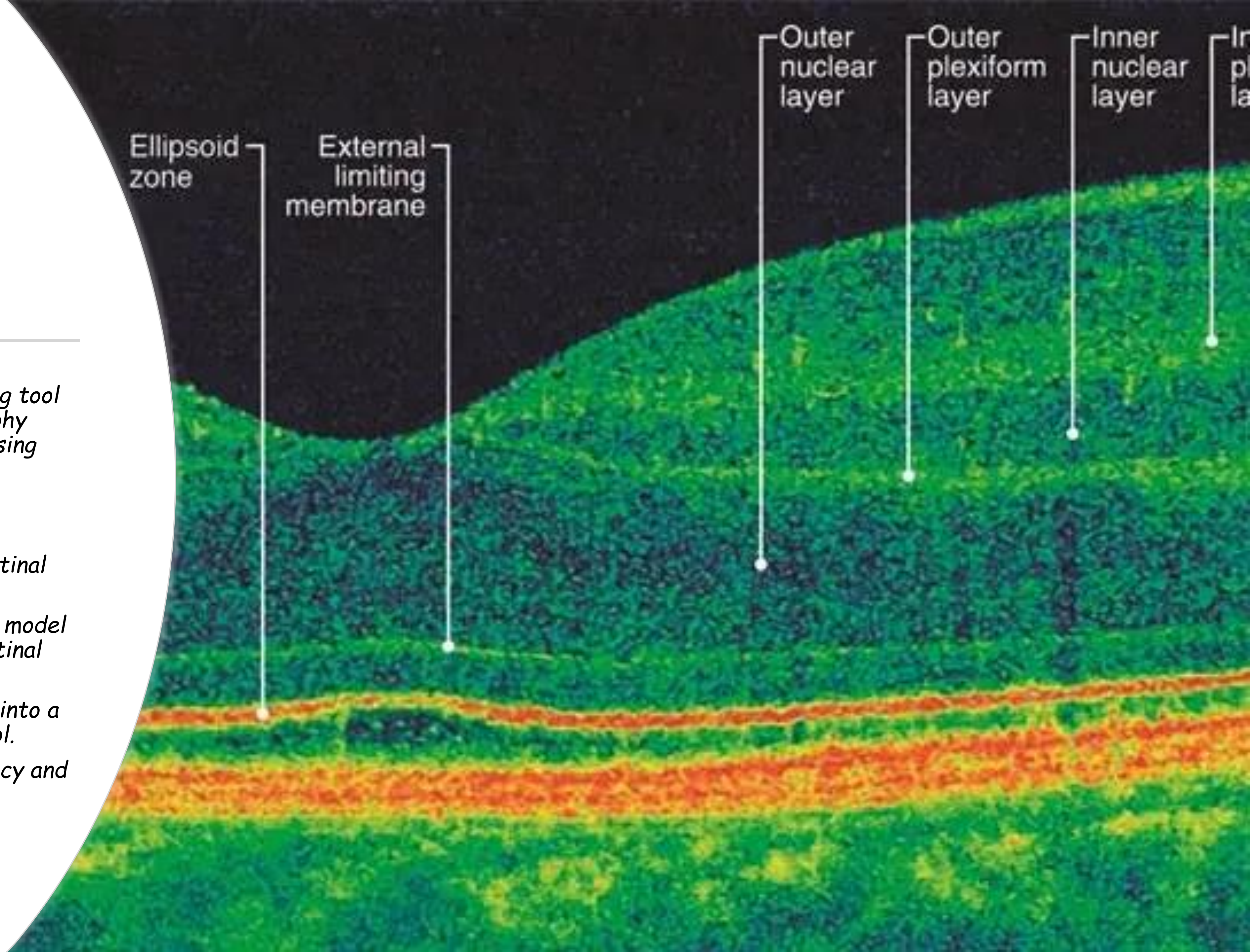


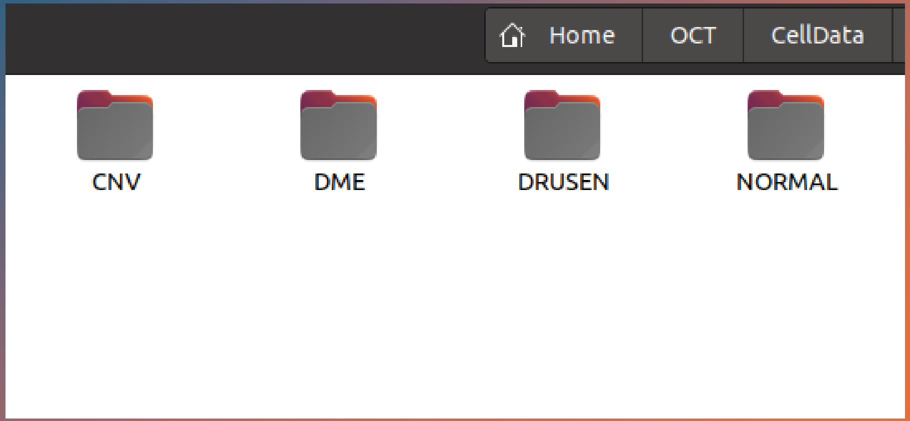
OPTICAL COHERENCE TOMOGRAPHY(OCT)

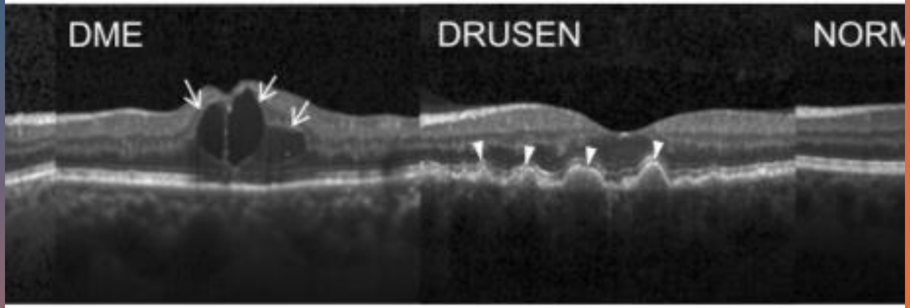
- ***Definition:*** *A non-invasive imaging technique that uses light waves to capture high-resolution, cross-sectional images of tissues, primarily the retina.*
- ***Principle:*** *OCT utilizes low-coherence interferometry, where reflected light from tissue and a reference mirror are combined to generate detailed images.*
- ***Applications:***
- ***Ophthalmology:*** *Diagnosing and monitoring retinal diseases like macular degeneration and glaucoma.*
- ***Cardiology:*** *Visualizing blood vessels and arterial walls.*
- ***Dermatology:*** *Imaging skin layers and detecting cancers.*
- ***Advantages:*** *Fast, high-resolution, real-time imaging.*
- ***Limitations:*** *Limited tissue penetration, requires specialized equipment.*

PROJECT DESCRIPTION

- ***Aim:*** *Develop an image processing tool for Optical Coherence Tomography (OCT) images to assist in diagnosing and managing retinal diseases.*
- ***Focus:***
  - *Develop a segmentation algorithm for detecting retinal layers.*
  - *Implement a classification model for identifying specific retinal diseases.*
  - *Integrate the algorithms into a user-friendly software tool.*
- ***Goal:*** *Improve diagnostic accuracy and efficiency in clinical settings.*







DATASET

- ***Large Dataset of Labeled Optical Coherence Tomography (OCT) and Chest X-Ray Images----Mendeley Data***

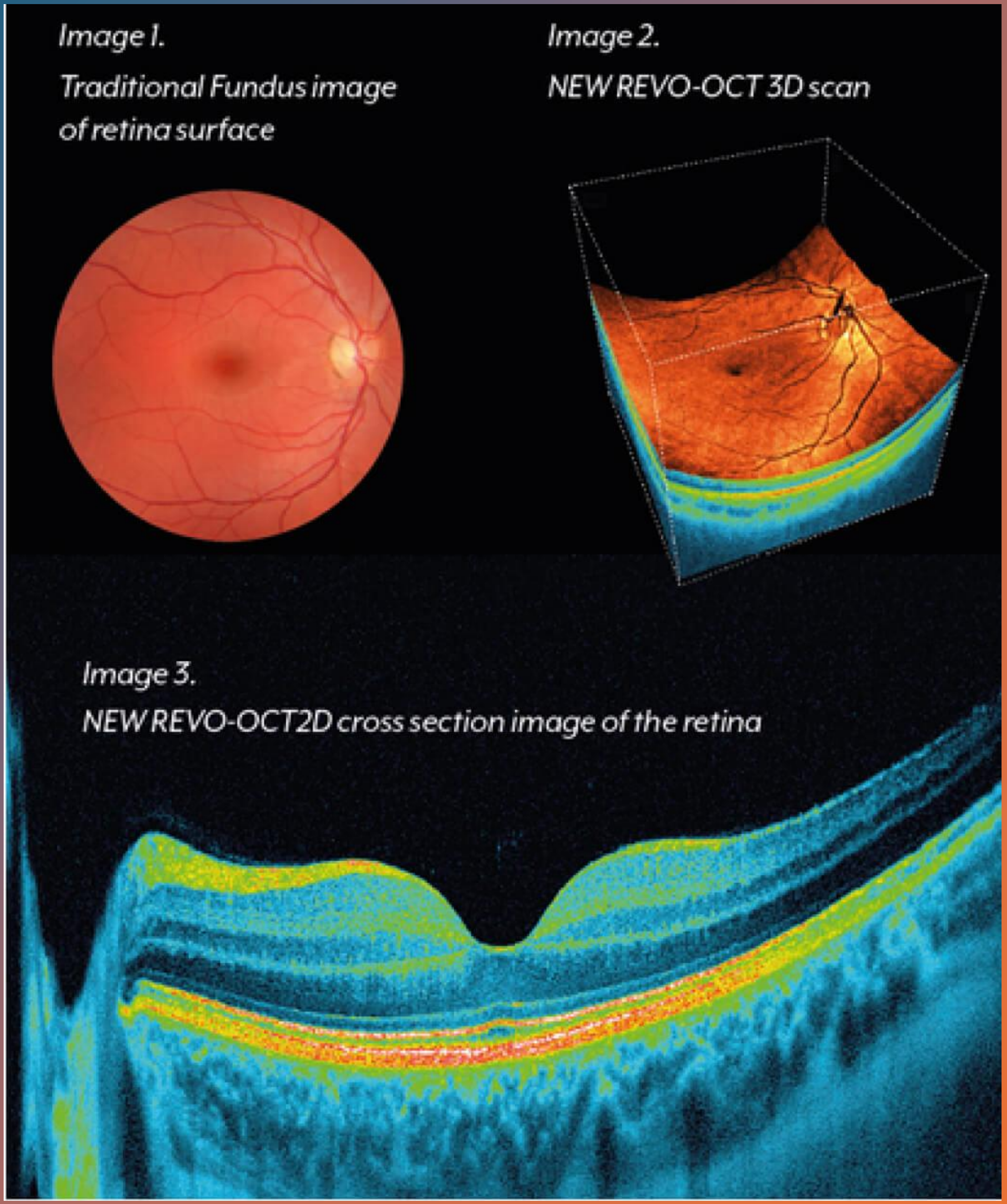
- ***Decription:***

  - *This dataset contains thousands of validated OCT and Chest X-Ray images described and analyzed in "Identifying Medical Diagnoses and Treatable Diseases by Image-Based Deep Learning". The images are split into a training set and a testing set of independent patients. Images are labeled as (disease)-(randomized patient ID)-(image number by this patient) and split into 4 directories: CNV, DME, DRUSEN, and NORMAL.*

  - ***Link:**https://data.mendeley.com/datasets/rscbjbr9sj/3*

PROJECT TIMELINE

- **Phase 1:** Data Acquisition and Preprocessing (Week 1-2)
- **Phase 2:** Algorithm Development (Week 3-5)
- **Phase 3:** Software Integration and Testing (Week 6-8)
- **Phase 4:** Documentation and Final Report (Week 9-10)



WORK DONE

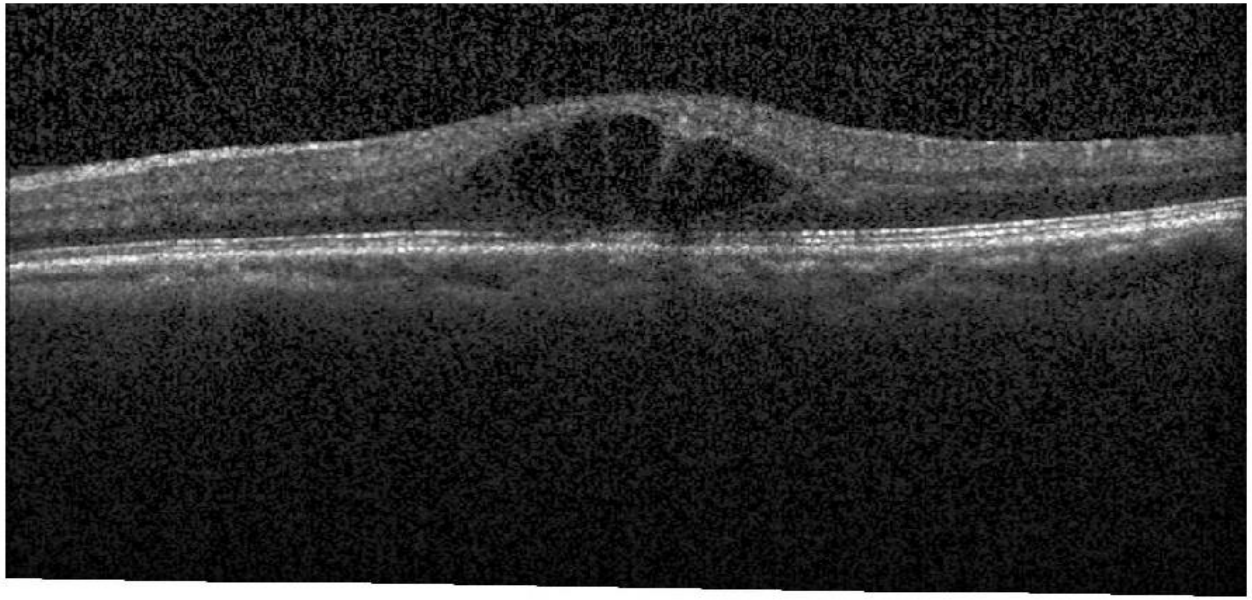
- *Acquired a balanced and well labeled dataset*
- *Preprocessed the data to enhance image quality, remove noise, and prepare the data for further analysis like segmentation or classification.*

DATA PREPROCESSING--- NOISE REDUCTION

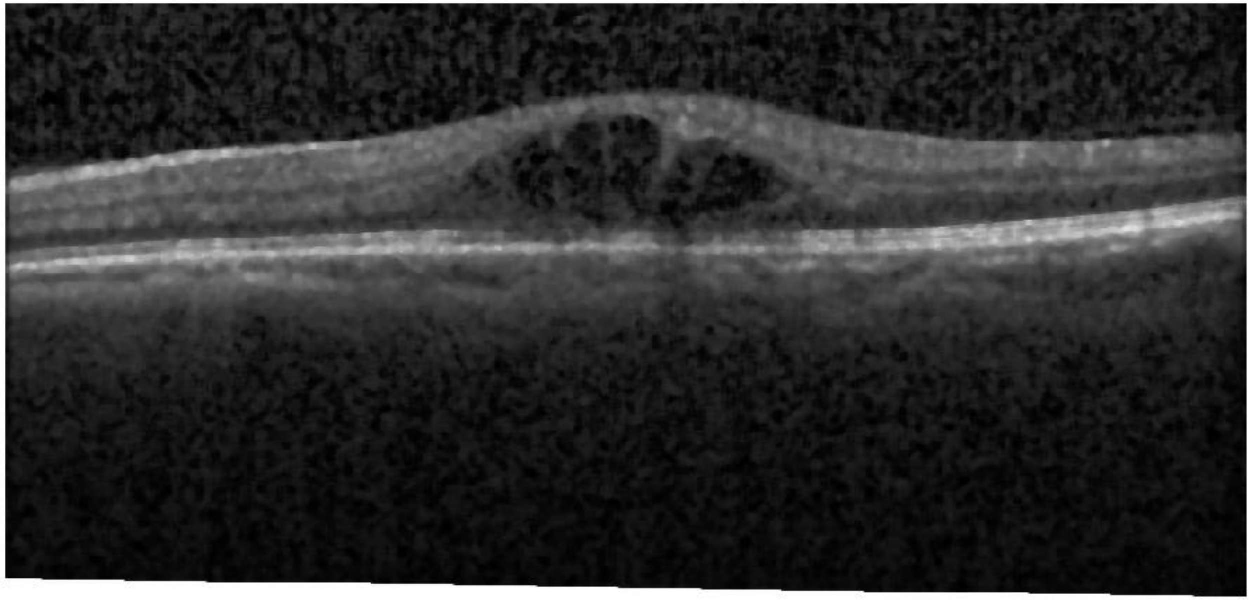
OCT images typically contain speckle noise, which is a granular interference that can hinder the visibility of structures.

Median Filtering: A median filter can reduce speckle noise while preserving edges.

Original OCT Image



After Median Blurring

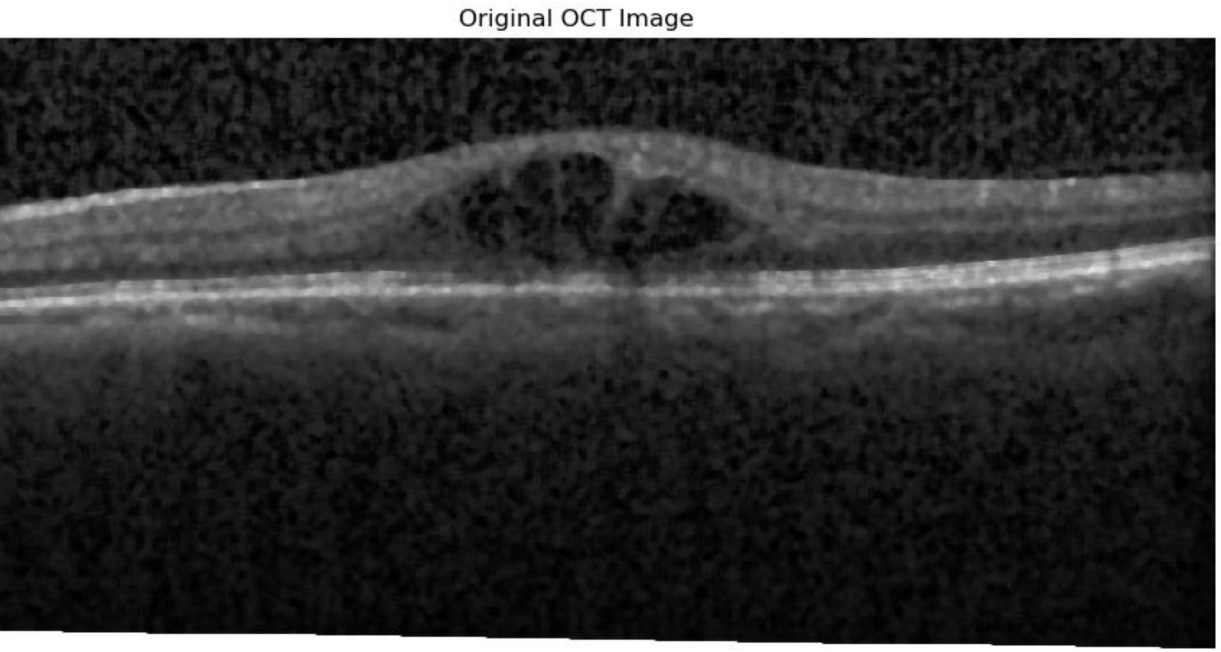


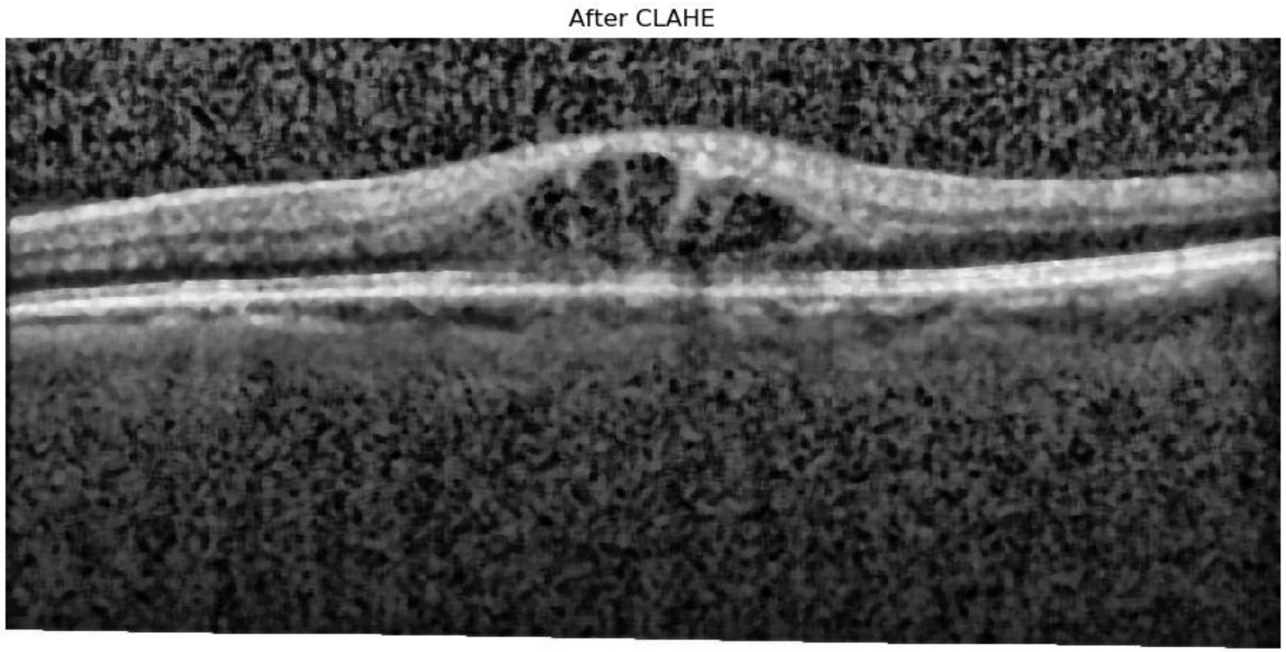
DATA PREPROCESSING --- CONTRAST ENHANCEMENT

Due to the low contrast between different layers in the retina, enhancing contrast is critical.

Histogram Equalization: This technique adjusts the image's intensity distribution to enhance contrast.

Adaptive Histogram Equalization (CLAHE): A more advanced method that works on small regions of the image to avoid over-amplifying noise.



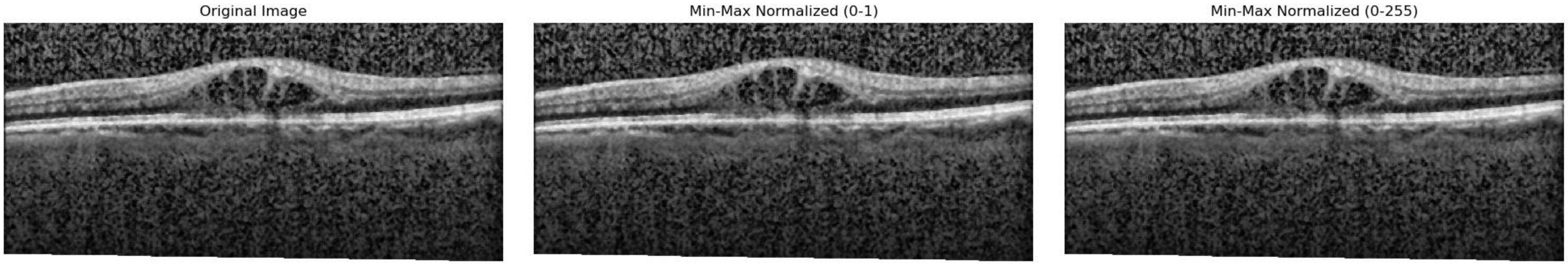


DATA PREPROCESSING---NORMALIZATION

Normalizing the pixel values ensures that all images are in a standard intensity range, important for machine learning models.

Min-Max Normalization: Rescales pixel values between 0 and 1 or 0 and 255.

Z-score Normalization: Normalizes based on the mean and standard deviation of the image intensities.

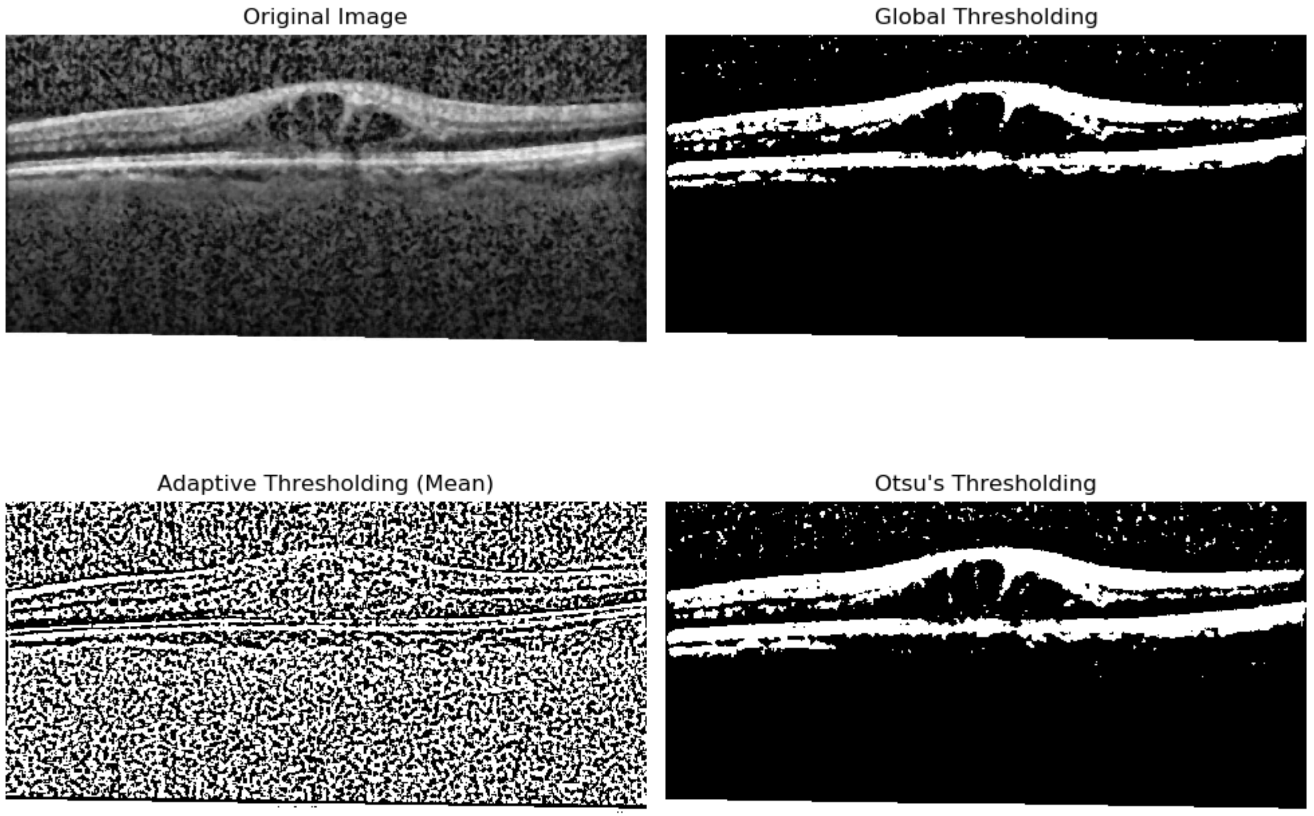


DATA PREPROCESSING --- ARTIFACT REMOVAL

OCT images can have shadows or other artifacts due to image acquisition methods.

***Shadow Compensation**: Techniques like shadow correction algorithms can help reduce these artifacts, from blood vessels or floaters.*

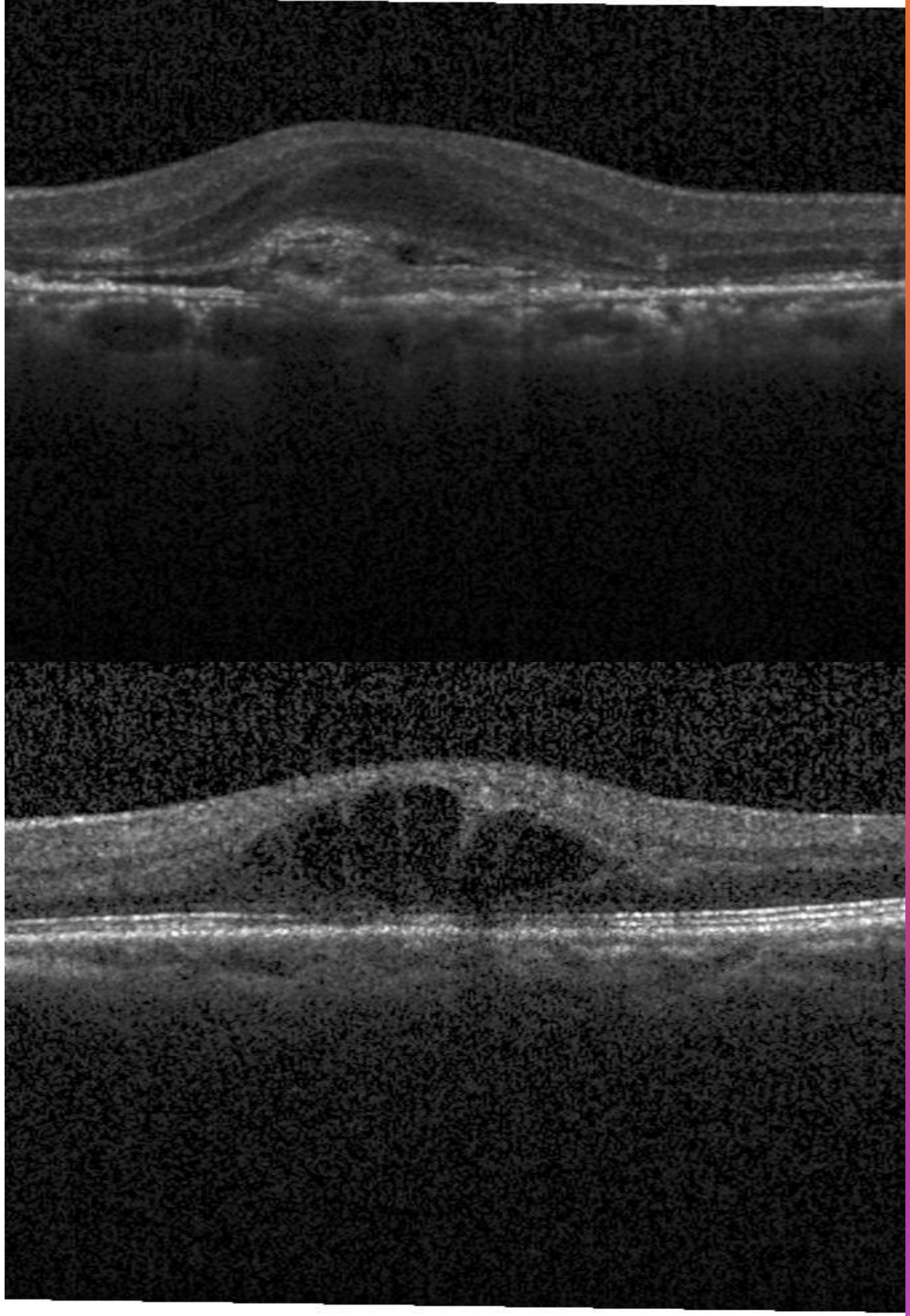
***Thresholding**: To remove non-retinal regions or outliers in the image.*



DATA PREPROCESSING --- IMAGE REGISTRATION

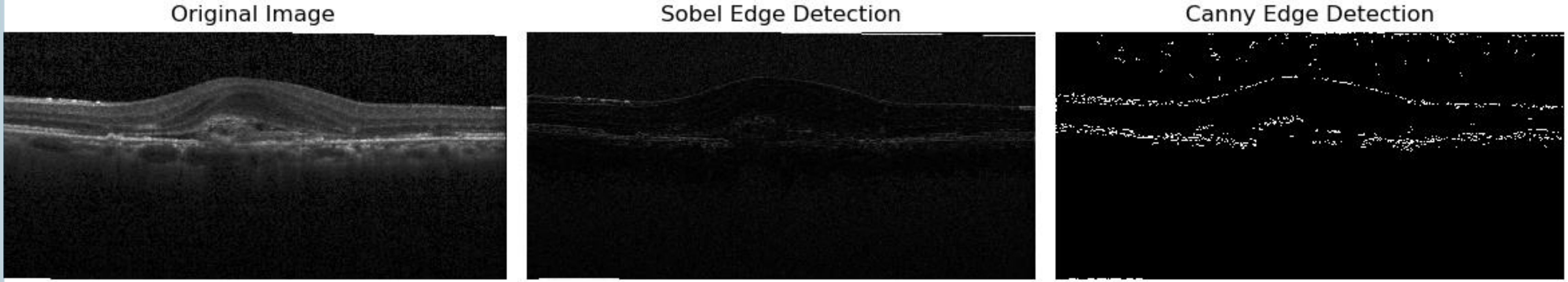
If multiple images or volumes are taken from different angles or over time, they need to be aligned.

Rigid or Non-rigid Registration: Aligns images to a common coordinate system to reduce variability from motion or acquisition angle.



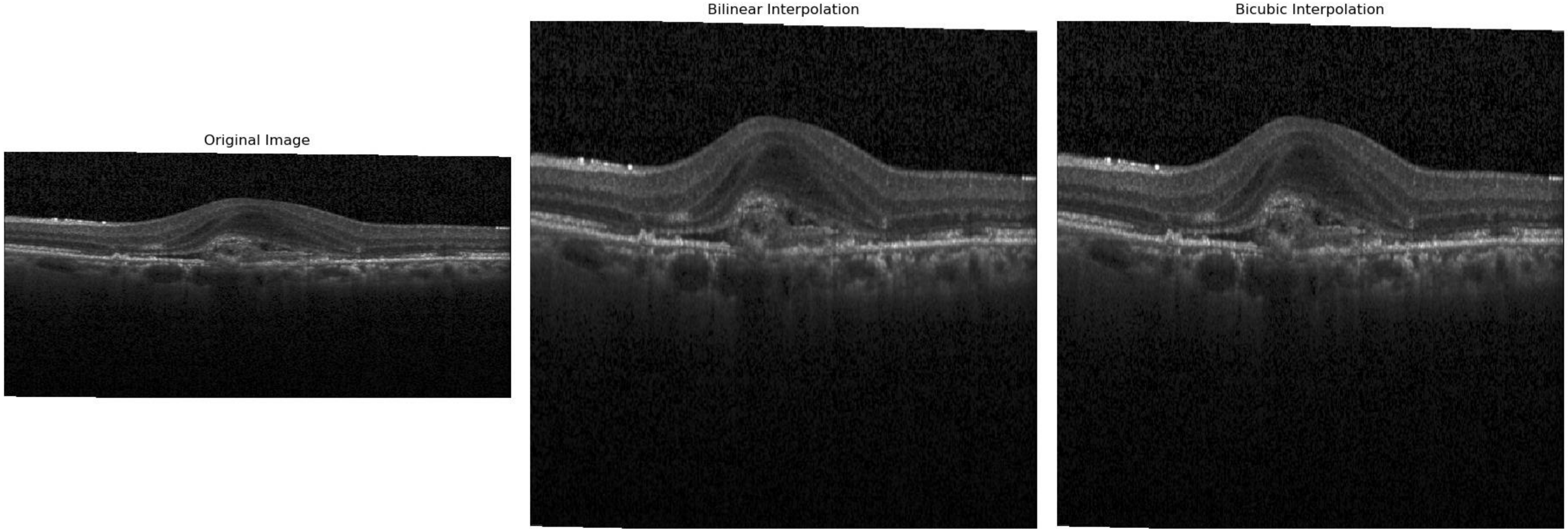
DATA PREPROCESSING---SEGMENTATION PREPROCESSING

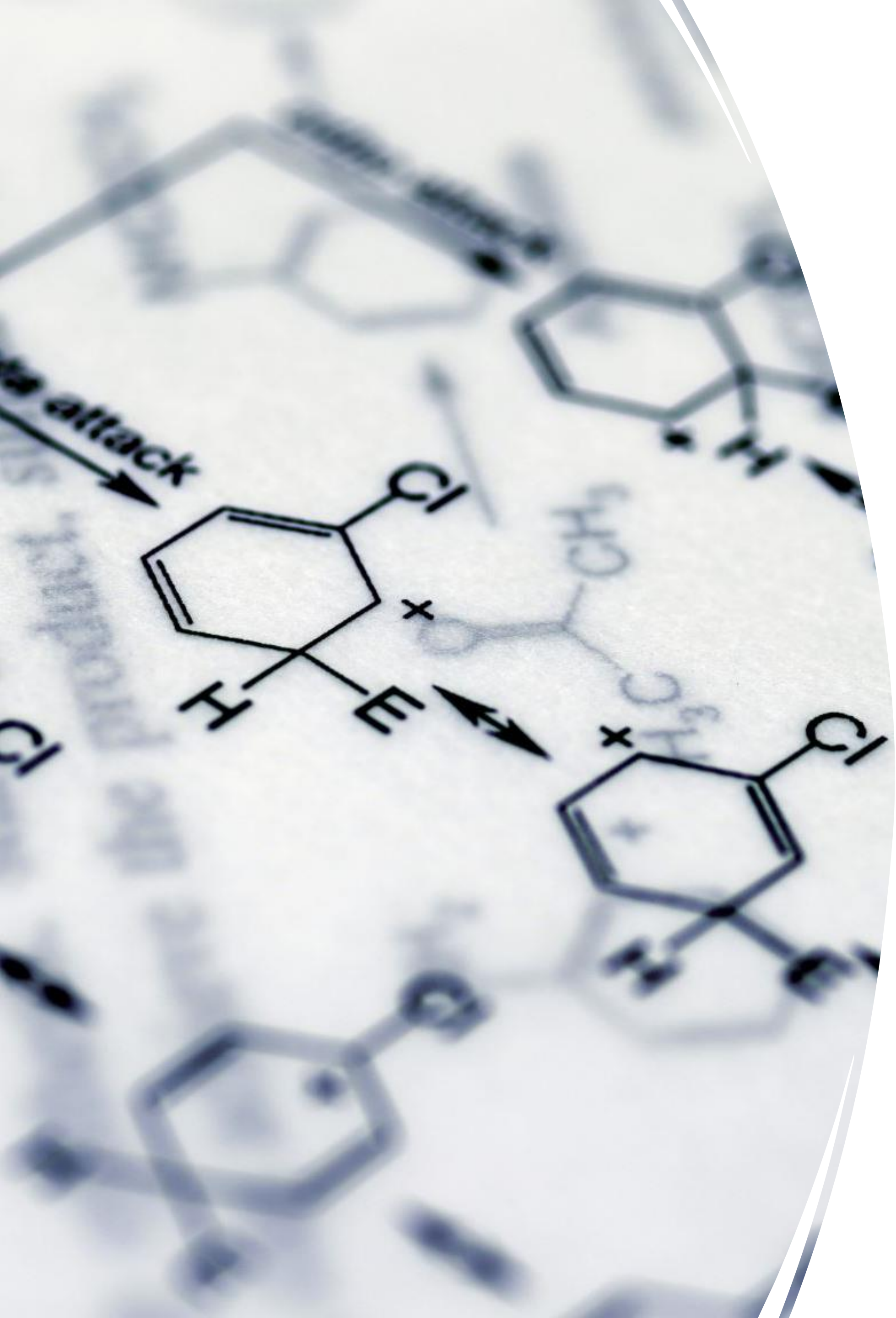
- *Preparing the image for segmentation involves further enhancement of features.*
- ***Edge Detection**: Detecting edges between different retinal layers using techniques like Sobel or Canny edge detection.*
- ***Binarization**: Converts the grayscale image into binary form to highlight key structures.*



Data Preprocessing---Resampling

- **Resampling** *can standardize the spatial resolution of the images, especially when working with datasets acquired from different devices.*
- ***Interpolation****: Bilinear or bicubic interpolation can be used for resizing images to a uniform resolution.*





ALGORITHMS USED FOR PREPROCESSING

Median Filtering (Noise Removal)

- ***Algorithm***: *Median Filter*
- ***How it works***: *Replaces each pixel with the median value of its neighbors to remove salt-and-pepper noise.*

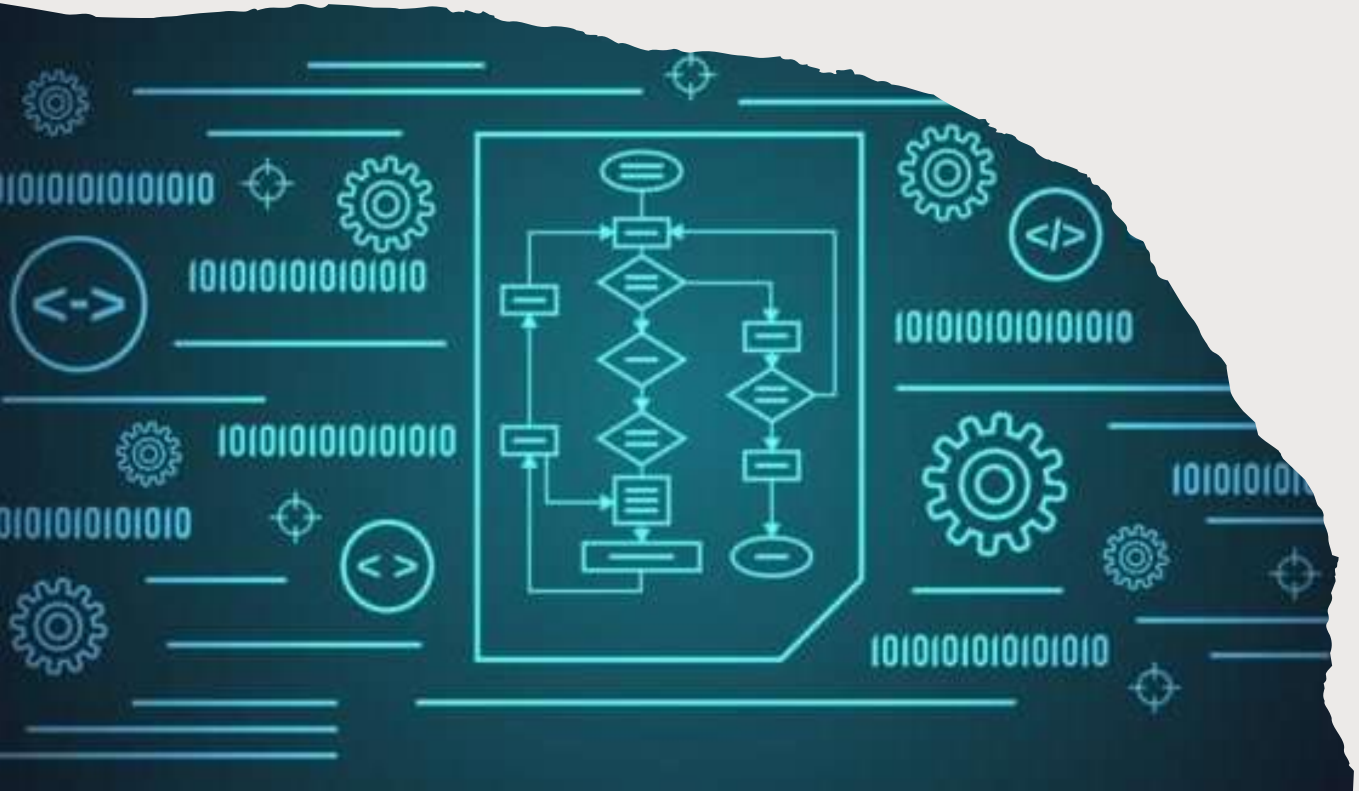
CLAHE (Contrast Enhancement)

- ***Algorithm***: *Contrast Limited Adaptive Histogram Equalization*
- ***How it works***: *Enhances local contrast by limiting amplification in each region and avoiding noise over-enhancement.*

Min-Max Normalization

- ***Algorithm***: *Linear Rescaling*
- ***How it works***: *Rescales pixel values to a range (0 to 1 or 0 to 255) using the formula:scaled_value = (pixel - min) / (max - min).*

ALGORITHMS USED FOR PREPROCESSING



- ***Z-score Normalization***
  - ***Algorithm***: *Standard Score*
  - ***How it works***: *Normalizes pixel values by subtracting the mean and dividing by the standard deviation, transforming the image to have mean 0 and std 1.*
- ***Shadow Compensation***
  - ***Algorithm***: *Shadow Correction*
  - ***How it works***: *Reduces shadows using histogram equalization or lighting correction to balance uneven illumination.*
- ***Thresholding (Binarization)***
  - ***Algorithm***: *Otsu's Method / Global Thresholding*
  - ***How it works***: *Converts grayscale to binary by finding a global or adaptive threshold to distinguish foreground from background.*
- ***Edge Detection***
  - ***Algorithms***: *Sobel / Canny Edge Detection*
  - ***How it works***: *Detects boundaries by computing intensity gradients (Sobel) or using a multi-step process (Canny) for sharp edge detection.*

RESULTS

- ***Noise Reduction***:
- *Salt-and-pepper noise effectively removed using median filtering.*
- ***Contrast Enhancement***:
- *CLAHE improved the visibility of retinal layers by enhancing local contrast without over-amplifying noise.*
- ***Edge Detection***:
- *Sobel and Canny methods highlighted clear boundaries between retinal layers, aiding in layer differentiation.*
- ***Binarization***:
- *Converted grayscale images into binary form, highlighting key retinal structures.*
- ***Normalization***:
- *Min-Max and Z-score normalization ensured consistent pixel intensity scaling for analysis.*
- ***Image Resizing***:
- *Bilinear/Bicubic interpolation standardized image resolution for uniform dataset preparation.*

Immediate Future Work—Retinal Segmentation Algorithm

- ***Objective***: *Develop a robust algorithm for segmenting retinal layers and pathologies.*
- ***Approach***:
- *Implement automated segmentation techniques to detect key retinal layers (e.g., ILM, RPE).*
- *Apply deep learning models for precise segmentation of retinal pathologies (e.g., macular edema, drusen).*
- ***Methods***:
- *Explore U-Net or fully convolutional networks (FCNs) for pixel-wise segmentation.*
- *Incorporate post-processing techniques (e.g., morphological operations) to refine segmented areas.*
- ***Expected Outcome***:
- *Accurate identification of retinal structures, improving diagnostic capabilities in OCT analysis.*

REFERENCE

- *Kermany, Daniel; Zhang, Kang; Goldbaum, Michael (2018), "Large Dataset of Labeled Optical Coherence Tomography (OCT) and Chest X-Ray Images", Mendeley Data, V3, doi: 10.17632/rscbjbr9sj.3*
- *Yojana, K., & Thillai Rani, L. (n.d.). OCT layer segmentation using U-NET semantic segmentation and RESNET34 encoder-decoder. Department of Electronics and Instrumentation Engineering, Annamalai University, Chidambaram, Tamilnadu, India.*
- *Mukherjee, S., De Silva, T., Grisso, P., Wiley, H., Tiarnan, D. L. K., Thavikulwat, A. T., Chew, E., & Cukras, C. (n.d.). Retinal layer segmentation in optical coherence tomography (OCT) using a 3D deep-convolutional regression network for patients with age-related macular degeneration.*


THANK YOU