

Segmentation of Retinal Structures Using Image Processing and Deep Learning Techniques with Applications in Retinal Disease Prediction

Abstract- Retinal vessels are the only vascular structure that is visible on the outside and can be captured through non-invasive procedures like using a fundus camera. These contain a wide range of information regarding a person's retinal health.

The vessel and optic disc segmentation directly aid in the diagnosis of various diseases, including, but not limited to, DR and glaucoma. The DR features include proliferate symptoms, which are red lesions (microaneurysms and haemorrhages) and bright lesions (soft and hard exudates). The glaucoma features are related to the rim, nerve fiber layer, circumlinear vessel, vessel trunk, optic disc and cup, and laminar dots.

Retinal vessel segmentation has various applications in the biomedical field. This includes early disease detection, biometric authentication using retinal scans, classification, and others. Many of these applications rely critically on an accurate and efficient segmentation technique. In the existing literature, a lot of work has been done to improve the accuracy of the segmentation task, but it relies heavily on the amount of data available for training as well as the quality of the images captured. Another gap is observed in terms of the resources used in these heavily trained algorithms. This work aims to address these gaps by using a resource-efficient unsupervised technique and also increasing the accuracy of retinal vessel segmentation using the Fourier decomposition method (FDM) along with the Gabor transform for image signals. A separate section makes a detailed comparison of the proposed method with several well-known methods and an analysis of the efficiency of the proposed method. The proposed method proves to be efficient in terms of time and resource requirements.

In our second contribution, we focus on thin vessel segmentation. This is an active research problem, with an emphasis on finding a universal approach for different types of fundus datasets. Enhancement of the thin vessels is the first and foremost task for proper segmentation, which is proposed to be done with the total variation (TV) decomposition method with layer-selective enhancement and illumination correction. The vessel segmentation task is carried out on two fronts. For thin vessels, we propose the attention UNet backbone, and for thick vessels, the modified Frangi method is used. The sensitivity performance surpasses the state of the art.

Next, once the vessel map is segmented out, we move on to diabetic retinopathy (DR) features. The automated and early detection of symptoms of DR would aid strongly with the diagnosis and cure. In this work, four proliferative symptoms, namely, microaneurysms (MAs), haemorrhages (HAs), hard exudates (HEs), and soft exudates (SEs), are segmented. The red lesions (MAs and HAs) are segmented using mean shift clustering, and the bright lesions (HEs and SEs) are segmented using a basic UNet, concatenated with handcrafted features or feature UNet (FUNet).

This study also presents the use of image processing methods for optic disc segmentation using fine-tuned MedSAM and SegFormer models, which both are transformer-based architectures. Our primary objective is to achieve accurate segmentation of the optic disc in fundus images, which is crucial in diagnosing retinal diseases such as glaucoma and diabetic retinopathy. To refine the segmentation results, we integrated specific pre-processing and post-processing techniques. A comparative study with existing top-tier models reveals that the transformer-based model markedly improves the accuracy of optic disc segmentation.

The automated classification of glaucoma has a major impact on the medical field, and when additional descriptive features of glaucoma are also taken into consideration, it provides further beneficial insights. The images from the JustRAIGS dataset are classified as glaucomatous or not using YOLO V8, and for further classification, the Swin transformer model (STM) is used with data augmentation and ROI limiting.