Chapter 5

Conclusion and Future Work

5.1 Conclusion

The thesis attempts a segmentation-based screening of Diabetic Retinopathy using 2-dimensional fundus images. In order to achieve the same, we have proposed an integrated pipeline with automated vessel extraction, red lesion segmentation, and then DR prediction. We have leveraged the combination of classical image processing techniques, and deep learning for segmentation purposes. The experimentation and validation of the algorithms are done using a variety of public fundus image databases, which has helped in improving the robustness of the proposed algorithms. An overview of medical image analysis, the disease Diabetic Retinopathy, its clinical features, and stages are discussed in chapter 1. In the same chapter, we also discusses the motivation behind this work, and thesis organization. Chapter 2 presents the unsupervised approach for retinal blood vessel segmentation. In this method, we exploit the concepts of classical image processing like wavelets, curvelets, and morphological operations to enhance the retinal blood vessel map. The algorithm is novel, data-independent, and provides a generic solution for retinal blood vessel extraction. In terms of performance, we achieve an average sensitivity and AUC-ROC of 0.764 and 0.960, respectively, while maintaining the average accuracy as 0.957. The proposed unsupervised method has outperformed even many supervised state-of-the-art methods.

In chapter 3, the same problem of vessel segmentation is approached in a supervised manner. The limitations due to data-scarcity are handled using a U-net based deep learning architecture, and a novel characteristic patch-based training. Here, the algorithm proposed in chapter 2 is used as the baseline to pre-process the fundus images and enhance the vessel features, which are finally fine-tuned using the deep model. This algorithm is developed to target two associated major challenges: 1. continuously varying thickness of vessels, and 2. in-homogeneous retinal background. While evaluating the performance, the best observed AUC-ROC is for DRIVE database with a value of 0.984, and minimum is for STARE, which is 0.978. Only slight deviation of curves from best to worst performance over four different databases, prove the stable and robust performance of the proposed method. The observed average sensitivity value is 0.829, which is better than the state-of-the-art.

Further, in chapter 4, we propose a novel red lesion segmentation algorithm, which is eventually used for DR screening. The targeted red lesions are the initial symptoms of DR. The idea is if we successfully segment the red lesions, we can detect DR in any stage, including the difficult early stages. Here, we use the vessel segmentation proposed in the previous chapter to extract the vessel map, which is then in-painted to focus on the abnormalities lying on the retina. The vessel-free fundus images are used to train a deep model for red lesion segmentation. We again employ a characteristic patch-based training of the deep model. It uses red lesion-specific patches along with the random patches. Moreover, we concatenate five handcrafted, intensity-based features to the model-extracted deep features for predication of the lesion map. As a final step, we evaluate the area of extracted lesions to decide the presence of lesions, which furthers predicts the DR. The proposed red lesion segmentation pipeline has successfully outperformed the other best state-of-the-art methods by 7 and 10%, respectively, in terms of mean area under PR curve. Also, the AUC-ROC obtained for DR screening process are 0.895, 0.872, for IDRiD and DDR datasets, respectively, which are better than the existing segmentation-based algorithms.

The segmentation-based disease diagnosis algorithms are always more reliable than a classification-based diagnosis. In segmentation, the experts can visualize and cross-verify the extracted abnormality. Thus, it fills the gap between the machine's prediction and the expert's verification.

5.2 Future Work

This thesis segments the retinal blood vessels and red lesions for a robust DR screening in any stage. Some ideas of future research extensions are as follows,

- Integration of the proposed pipeline with an imaging device to create a complete solution for real-time screening. The idea is to work at community-level to create an impact at a large scale and share some burden of medical experts.

- The segmentation-based gradation of DR can be one more extension of this thesis. It will be a classification of fundus images into different stages of DR based on abnormality-segmentation. This will require a precise segmentation of different abnormalities belonging to different stages of DR like bright lesions, neovascularisation, etc. It will help in the follow-up process after DR screening.

- We are planning to combine all the datasets to train a common model for which we are exploring different segmentation models like, LeViT-NET with U-NET and Inception-ResNET. For training the common model, we'll have to work on the harmonization of the data as well.

- Some subjects, like premature infants, have a thin retinal layer. In such cases, choroidal vessels are prominently captured in the fundus images. In the proposed method, we could not distinguish between the two kinds of vasculature. In the future, we can extend the proposed vessel extraction to handle the retinal and choroidal vessels separately. It can help in the diagnosis of diseases like Retinopathy of Prematurity.

- The retinal vessel-diameter estimation and artery-vein classification can be other two extensions in the vessel segmentation process. These factors can help in the diagnosis of many other retinal and cardiovascular diseases.