ABSTRACT

Diabetic Retinopathy is an eye disease and a common complication of diabetes that can cause vision loss if left undiagnosed at an initial stage. It is the prime cause of blindness in the working age population of the world. Colour fundus images are used by ophthalmologists to study eye diseases like diabetic retinopathy. Early detection of diabetic retinopathy through regular screening is particularly important to prevent vision loss. However, with a large number of patients undergoing regular screenings, more amount of time is needed for ophthalmologists to analyse and diagnose the fundus images. In India, there are not enough resources, in terms of time and available expert ophthalmologists, for carrying on an extensive screening. Thus, a reliable automatic tool for diagnosis of diabetic retinopathy is strongly needed.

Any automatic tool for diagnosis of diabetic retinopathy must go through some well defined steps. First, it has to detect the major anatomical structures of the retina viz blood vessels, optic disc and fovea. Second, it has to identify abnormalities in the retina like hard exudates, cottonwool spots, hemorrhages and microaneurysms that cause diabetic retinopathy.

This thesis mainly focuses on developing a Fundus Image Analysis system that extracts the anatomical and abnormal features of the retina in order to diagnose diabetic retinopathy. The research is carried out in six phases: In the first phase, Histogram Matched Local
Relative Entropy (HMLRE) method is developed to segment the vasculature of fundus images. This method uses the intensity information of red and green channels of the same fundus image to correct the non-uniform illumination in colour fundus images. Matched filtering is employed to improve the contrast of retinal blood vessels against the background. The enhanced retinal blood vessels are then segmented by using Local Relative Entropy based thresholding that can efficiently maintain the spatial structure of the vascular tree segments. Experimental results of the HMLRE method using STARE (Structured Analysis of the Retina) and DRIVE (Digital Retinal Images for Vessel Extraction) databases show that the area under receiver operating characteristic curve and average accuracy of segmentation are better compared to existing unsupervised and supervised methods.

In the second phase, two efficient approaches are proposed for automatic localization and contour detection of optic disk in ocular fundus images. The proposed optic disk localization approach uses the vessel branch with the most vessels to localize the optic disk. The contour detection algorithm involves colour morphology in Lab space and Geometric active contour model with new variational formulation to estimate the contour of optic disk. The proposed optic disk localization and contour detection methods yielded high accuracies compared to existing methods.
In the third phase, a model based approach to detect vascular arcade, macula and fovea is proposed. This approach uses the segmented blood vessels as input to identify the horizontal raphe of the fundus image. Macula and fovea are detected using this horizontal raphe. A fundal coordinate system centered on fovea is established on the fundus image. This approach detects fovea with an accuracy of 94.86%.

Fourth phase contains the development of spatially weighted fuzzy c-means (SWFCM) clustering method to detect bright lesions such as hard exudates and cottonwool spots in fundus images. In this method, the fundus image is first preprocessed to enhance the contrast of the bright lesions. Next, the entropy feature is utilized to eliminate optic disk. To extract the enhanced bright lesion regions, an approach based on SWFCM clustering is proposed. This clustering algorithm is designed by including the spatial neighbourhood information into the standard fuzzy c-means (FCM) clustering technique. The true bright lesions are distinguished from bright non-lesions using k-nearest neighbour (KNN) and support vector machines (SVM) classifiers. For image based evaluation, this method achieved sensitivity and specificity of 100% and 88.23% respectively, which are much better, compared to other FCM based methods.

In fifth phase, a hybrid detection method is proposed to detect dark or red lesions such as microaneurysms and hemorrhages in fundus images. This method comprises of three stages. First, the green channel of the colour retinal image is preprocessed using polynomial
contrast enhancement. Second, the candidate dark lesion objects are extracted from the contrast enhanced fundus image. A novel method is developed to extract candidate dark lesions based on matched filtering and local relative entropy thresholding. The performance of this technique is compared to mathematical morphology based dark lesion detection method. A hybrid method that combines both detection schemes is also tested for better segmentation. The final stage classifies true dark lesions from dark non-lesions using knn and svm classifiers. For image based evaluation, this method has resulted with sensitivity and specificity of 100% and 87.5%, respectively.

In the last phase, a method to grade diabetic retinopathy and macular edema based on the detected bright lesions and dark lesions is presented.

The methods developed in this thesis make it possible to conceive a Fundus Image Analysis system that is useful in assisting an ophthalmologist’s diagnosis by providing second opinion and also functions as an automatic tool for the mass screening of diabetic retinopathy. The proposed Fundus Image Analysis system is also designed to provide the spatial distribution of abnormalities centered on fovea such that an ophthalmologist can make a detailed diagnosis.