Chapter 1

Introduction

1.1 General

Recent advances in digital imaging and computing power have made it possible to use data provided from medical images in new and revolutionary ways. This has also led to considerable interest in the development of automatic medical diagnosis systems to improve the services provided by the medical community. These systems aid physician’s to diagnose, measure important anatomical structures, monitor changes by comparing sequential images and plan for the better treatment. They also relieve physicians of repetitive work, decreases fatigue and increases efficiency in work.

In clinical ophthalmology, colour retinal images acquired from digital fundus camera are widely used for the detection and diagnosis of diseases related to eye, hypertension and various vascular disorders. Of the many complications of diabetes, visual impairment is perhaps the most feared. Mainly the distressing are in the retina leading to a condition called retinopathy. Diabetic retinopathy is a disorder of the retinal vasculature that eventually develops to some degree in nearly all patients with long standing diabetes mellitus (Emily et al., 2003). According to World Health Organization (WHO), number of adults with diabetes in the world would increase alarmingly from 135 million in 1995 to 300 million in 2025. In India, this increase is greatest that is
Diabetic retinopathy is one of the major causes of blindness in the working age population around the world. The prevalence of retinopathy varies with the age of onset of diabetes and the duration of the disease: in younger patients (below 30 years of age) the prevalence of retinopathy is minimal during the first 5 years but increases to greater than 95% after 15 years of diabetes (Reema M. et. al., 2007). In contrast among patients whose onset of diabetes occur after the age of 30, up to 20% may have signs of retinopathy on presentation with the prevalence in this group rising more slowly to approach 60% after 15 years of diabetes. Unfortunately, because visual loss is often a late symptom of advanced diabetic retinopathy, many patients remain undiagnosed even as their disease is causing severe retinal damage. It is shown that timely diagnosis and referral for management of diabetic retinopathy can prevent 98% of severe visual loss. First step in prevention of the disease is to have a regular diabetic retinopathy screening program. The process involves acquiring the retinal image using standard digital colour fundus camera. The ophthalmologist uses images to aid in diagnosis, to make measurements of the normal anatomical structures, to locate abnormalities and to look for a change in lesions.

Given the number of diabetes patients screened yearly, the number of retinal images generated is large. The high cost of examination and the shortage of ophthalmologists, especially in rural areas, are prominent factors that hamper patients from obtaining regular examinations (Abràmoff et al., 2008). Therefore, the need for automated retinal image processing system arises that can screen the initial set of images for any signs of abnormalities. Only those images with lesions can be forwarded to ophthalmologists for further analysis. This could save the workload of ophthalmologists and assist them to analyze a large database of retinal images in a short period of time. A
fully automated system can detect early signs of diabetic retinopathy, provide objective assessment, monitor the progression of disease and monitoring of the onset and progression of the disease, as well as analysis of anatomical structures.

1.2 Objectives and Scope

The primary objective of evaluating and managing diabetic retinopathy is to prevent, retard, or reverse visual loss, thereby maintaining or improving vision-related quality of life. In ophthalmology, for diagnosis of diabetic retinopathy, digital colour retinal images are becoming increasingly important. In computer based retinal image analysis system, image processing techniques are used in order to facilitate and improve diagnosis. Manual analysis of the images can be improved and problem of detection of diabetic retinopathy in the late stage for optimal treatment may be resolved.

The automatic detection of landmark anatomical structures and lesions are needed during the mass screening for the detection and diagnosis of diabetic retinopathy. The anatomical structures detection helps in characterizing the detected lesions and in identifying false positives. Lesion detection is essential for monitoring purpose and to classify the severity stages of the disease. Based on these the main objectives of the work are summarized as follows.

- To automatically detect the following normal features in retinal image to improve the performance of pathology detection.
  (i) Automatic detection of optic disc boundary
  (ii) Automatic detection of macular region
  (iii) Automatic detection of retinal blood vessels
To automatically detect lesion, i.e., exudates in retinal images for the early detection of diabetic retinopathy.

To develop an automatic retinal analysis system to classify severity of the disease.

Current techniques of diabetic retinopathy detection and assessment are mostly manual, expensive, and potentially inconsistent requiring highly trained staff to facilitate the process by searching large number of retinal images. It is hoped that the proposed system can assist ophthalmologists to make diagnosis more effective and provide an automatic cost effective tool for the mass screening of retinopathy.

### 1.3 Thesis Outline

In this thesis, automatic methods to analyze the digital retinal images for detection of diabetic retinopathy are proposed. The overall retinal image analysis system is shown in the Figure 1.1. The system is capable of choosing the diabetic patients who need further examination during the mass screening. It is also able to provide the severity level of maculopathy, a sight threatening complication of diabetic retinopathy. Few of the retinal images acquired during the examination may be of inadequate quality for manual analysis. Factors that affect the clear visualization of retina are due to operator inexperience with fundus photography, problems in patient focusing and insufficient light reaching retina. In the first stage, such colour retinal images are preprocessed using local contrast enhancement technique. Next, only the green component in the colour image is extracted as it provides the maximum details about structures present in the retinal image.
Fig. 1.1: Outline of the proposed retinal image analysis system.
Once the images have been preprocessed, the landmark anatomical structures: optic disc, fovea and blood vessels are detected. Localization of the optic disc is required as prerequisite for the subsequent stages for identification of other anatomical structures in an image. During the exudates lesion identification, many false positives arise due to other pale objects including light reflections, cotton wool spots, and most significantly, the optic disc. The localization and segmentation of optic disc boundary is achieved in two step approach. First, the approximate center of optic disc is detected in the retinal image using iterative thresholding method followed by connected component analysis. It provides baseline in finding out its exact boundaries. Then, the geometric model based implicit active contour is employed to obtain accurate optic disc boundary. Fovea or macula encircling helps establishing statistics regarding lesions position for disease gradation. It is reported in Gagnon L. et al., 2001, that the distance and position of fovea with respect to the optic disc remains relatively constant. Once the optic disc is detected, the fovea is localized by finding the darkest region in the image following the prior geometric criteria based on the eye’s anatomy.

Automatic segmentation of the vasculature in retinal images is important in the detection of diabetic retinopathy that affects the morphology of the blood vessel tree. The proposed retinal vessel detection method is comprised of two steps. The blood vessels will be oriented along different directions and they also vary in thickness along their length. Initially, Gabor filters tuned to particular frequency and orientation are used to enhance the blood vessels suppressing the background. A bank of twelve Gabor filters with the range of 0° – 170° degree in 15° degree steps are used to enhance the retinal blood vessels. Filtering involved computationally intensive convolution operation. Therefore, by experimentation it is found that increasing the number of Gabor filters beyond twelve did not result in high increase of vessel
detection accuracy. It is also found in the literature (Chaudhuri et al., 1989) that vessel segments lying within $\pm 7.5^\circ$ degree of direction of chosen kernel will respond well. The colour image does not provide much information to distinguish vessels from background. Therefore, the image was decomposed into 3 channels – red, green and blue (each one of them represented in the scale of gray). Only the green channel image is used for further processing as it provided more contrast. It also reduced the computational cost of the algorithm by three fold. Maximum Gabor response image results in enhanced vessels. In the next step, entropy based thresholding based on gray level co-occurrence matrix is employed for the segmentation of the vessel pixels. The performance of the method was tested on two sets of publicly available retinal databases. Then, the accuracy of the method is compared in terms of pixel resolution and image based criteria against a provided pixel-level ground truth dataset.

Hard exudates are abnormal lesions caused by diabetic retinopathy in a diabetic’s eye and they are considered to be bright intensity regions in the retinal images. First step in the identification of exudate regions is the detection and masking of optic disc to avoid false positives. The exudates regions are detected using a combination of dynamic clustering and mathematical morphology. The initial candidate exudate regions are obtained by clustering the intensity difference image in the image space. For the fine segmentation of the exudates, morphological reconstruction technique is employed. Finally, the exudate regions are obtained by thresholding the difference between the original image and the reconstructed image. The threshold varies from one image to another, so an entropic thresholding technique is used for the automatic calculation of optimal threshold. Image based method is employed to verify the diagnostic accuracy of the method. Here each single exudate lesion is regarded as an individual connected region, where this region can be comprised of one or more pixels. Each
abnormal retinal image can be segmented into a number of exudate regions. Finally, the performance of the method was validated by the ophthalmologists. Also a standard dataset was used to evaluate the image based exudate detection.

Next stage in the automatic retinal analysis system is to make a decision regarding the severity level of the diabetic maculopathy. The presence and spread of exudates determine the severity of the disease as mild, moderate and severe. Localization of exudates in the area of macular region lead to a condition called Clinically Significant Macular Edema (CSME). If the exudates are very apparent and affect the center of macular region, the fovea centralis, visual function will be significantly and irreversibly damaged. After the detection of macula and exudates, the macular region is identified and it is divided into marker regions. Automatic grading of diabetic maculopathy is done according to the international clinical diabetic macular edema disease severity scale. According to Mead A. et. al., 2001, a minimum standard of 80% sensitivity and 95% specificity for the detection of diabetic retinopathy is to be achieved by any method. The result obtained from the proposed work has met the requirement as comparable to human expert. A Graphical User Interface (GUI) has also been developed that can be used by clinicians during the mass screening.

1.4 Organization of the Thesis

The thesis is organized according to the respective identification tasks of the automated retinal image analysis system for the detection of diabetic retinopathy as follows.

Chapter 2 introduces the background of medical domain. It includes anatomy of the ocular fundus and the landmark retinal structures. Eye
complications of diabetes, i.e., retinopathy and its sight threatening stage called maculopathy are discussed. This chapter also provides a literature review on the retinal image analysis systems and algorithms.

**Chapter 3** presents acquisition of retinal image and pre-processing methodologies. The specifications of the retinal images that are used in this work are discussed. Details of retinal images obtained from standard databases are mentioned. In the pre-processing step colour normalization, local contrast enhancement and extraction of green component in the retinal image is described.

**Chapter 4** presents the automatic segmentation of retinal vessels. The properties of the vessels and how they are used to design the Gabor filter is described. A set of Gabor filters oriented along different directions are used to enhance the vessels. It is followed by segmentation of vessel pixels using automatic calculation of threshold. The performance of the method is analyzed and compared with other vessel segmentation approaches.

**Chapter 5** presents the automatic localization of landmark feature of retina, the optic disc. It starts with the detection of approximate center of disc using iterative thresholding and connected component method. Followed by, the segmentation of exact boundary of optic disc based on geometric active contour model. Then the size and location of optic disc is used to identify the macula, the center of ocular fundus.

**Chapter 6** explains the automatic segmentation of exudate lesions. The hybrid method using K-Means clustering for coarse segmentation and mathematical morphology for fine segmentation are discussed. The performance of the method on two different set of databases are presented. The chapter also describes the automatic grading of diabetic
maculopathy severity level. Development of the GUI for mass screening of retinopathy and its snap shots are also provided.

Chapter 7 presents thesis conclusions on the basis of analysis and discussion and highlights the contributions of this work. It also includes scope for improvement and future direction of research.