Chapter 1

Introduction

This chapter presents a background to discuss about the cross-sectional view of the human eye, retina, related diseases, our motivation behind the present work, and objectives of this thesis. Finally, the chapter concludes with an organization of this thesis.

1.1 Background

Vision is one of the most important gift which God has offered us. It is said, “health is wealth”. But not wealth in the universe is equivalent to the vision gift.The human eye is the most important organs in the human body. It is very sensitive and exposed to a variety of diseases that’s why we should take a lot of care to protect it and keep safe. First, start

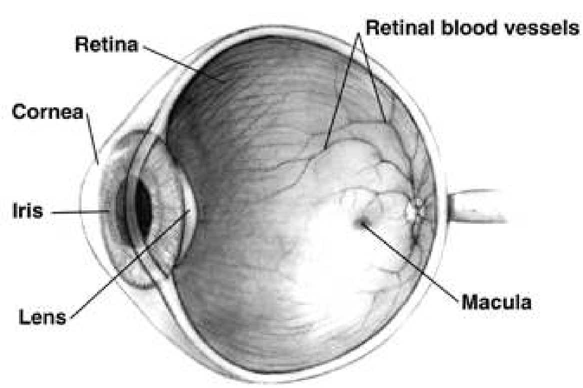

Figure 1.1: Cross-sectional view of human eye.
[1]

the discussion about cross-sectional view of human eye as shown in Figure 1.1 [1].

- When light strikes the eye, the first part it reaches is the cornea, a dome positioned over the center of the eye. The cornea is clear and refracts, or bends, the light passing through it.

- Light then reaches the pupil and iris. These parts of the eye are responsible for regulating the amount of light that gets through. Too much or too dim light can hinder one's vision. The muscular iris moves to shrink the pupil if there is too much light and widen it if there is not enough. This is an involuntary function, controlled by the brain.

- Deeper inside the eye is the lens, which further refracts light and helps create a more precise image. The shape of the lens can be manipulated to help the eye see things better depending on the proximity of the object being viewed. The lens flattens to properly focus light received from distant objects and becomes rounder for nearer objects. This is also an involuntary action.

- Once past the lens, light strikes the millions of photoreceptors cells in the retina. There are two types of photoreceptors, rods and cones, which are named for their shape. Rods work in less light and create black-and-white images, and cones work in bright light and allow for color vision.

There are three types of cones: one sees red, one sees green, and one sees blue. Lack of one or all of these are the main cause of the color blindness. A lack of the green or red cones that means there are red-green color blindness which is more common than lack of blue cones or lack of any cones at all. The retina's photoreceptors react to the light that hits them and cause nerve impulses to be sent to the brain via the optic nerve. The brain interprets and classifies the visual information. The "white of the eye" is the tough outer shell called the sclera. Inside the eye is a fluid called the vitreous humor, a jelly-like substance that helps give the eye its shape. Another fluid of the eye is the aqueous humor, which lubricates the iris.

As per previous discussion the retina is the third and the inner coat of the eye, which is a light-sensitive layer of tissue. Ophthalmology is a branch of medicine and their primary concern is to handle the issue of vision loss that is heavily dependent on retinal images.

A typical retinal image with normal features include optic disc, fovea, and the blood vessels are shown in Figure 1.2. The optic disc is the location where ganglion cell axons exit the eye to form the optic nerve. The fovea is the part of the retina responsible for sharp central vision. It has the highest density of photoreceptor cells and approximately 50% of the nerve fibers in the optic nerve to carry the information from the fovea. The blood vessels or vascular are the circulatory system that supplies blood to the different layers of the retina.

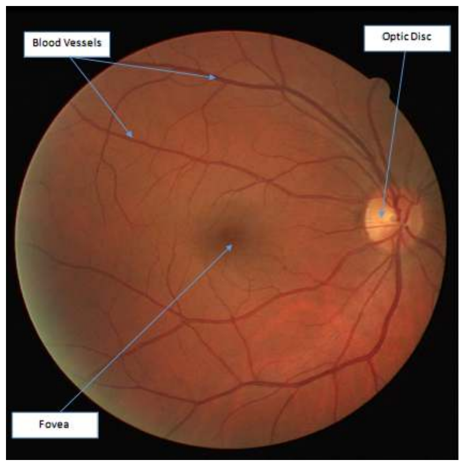

Figure 1.2: Retina image captured by fundus camera.
[2]

Retinal photography requires the use of a complex optical system, known as fundus camera. To capture the retinal image, it is usually required that the iris be dilated with pharmaceuticals and captured with a mydriatic fundus camera where mydriatic means the iris must be dilated. A fundus camera is a specialized low-power microscope with an attached camera designed to photograph the interior part of the eye in association with the optical system of the eye. The non-mydriatic fundus cameras can also be used in case of natural dilation of the patient in a dark room. These cameras use near infrared light to focus and a white light arc lamp to produce a flash that illuminates the retina. The retinal images are captured using a conventional digital camera, attached to the retinal camera body designed to image the eye fundus in association with the optical system of the eye [3], [4], [5]. The image captured by using a Canon CR5 non-mydriatic 3-CCD camera with a 45^o field of view is shown Figure 1.2. The fundus camera normally operates in three modes. In Color photography the retina is examined in full color under the illumination of white light. In Red-free photography, the vessels and other structures are improved in contrast and the imaging light is filtered to remove the red colors. The fluorescent angiograms are acquired using the dye tracing method. A sodium fluorescein or indocyanine green is injected into the blood, and then the angiogram is obtained by photographing the fluorescence emitted after illumination of the retina with blue light at a wavelength of 490 nanometers [6].

1.1.1 Retinal Disease

Many important diseases manifest themselves in the retina and find their origin in the eye, the brain, or the cardiovascular system. There are various diseases that can be studied via retinal image analysis which is as follows: [6]

- **Age-related macular degeneration:** Age-related macular degeneration (AMD) is the most common cause of visual loss and is a growing public health problem. AMD has two major forms dry and wet AMD. The dry AMD typically leads to gradual loss of visual acuity. The Wet AMD, known as choroidal neovascularization, is the most visually threatening form. Its natural course is a rapid deteriorating acuity, scarring of the pigment epithelium, and blindness.

- **Diabetic retinopathy:** Diabetic retinopathy (DR) is a complication of diabetes mellitus and the second most common cause of blindness and visual loss. In the eye, hyperglycemia damages the retinal vessel walls and can lead to the growth of new blood vessels (neo-vascularization), which may bleed and cause retinal detachment. It can also cause diabetic macular edema and damage the photoreceptors because of breakdown of the retinal blood vessels barrier [7].

- **Glaucoma:** Glaucoma is a third leading cause of blindness and characterized by gradual damage to the optic nerve and resultant visual field loss. Early diagnosis and optimal treatment have been minimizing the risk of the visual loss due to glaucoma [8].

- **Vascular disease:** Cardiovascular disease manifests itself in the retina in a number of ways. Hypertension and atherosclerosis cause changes in the ratio between the diameter of retinal arteries and the veins, known as the A/V ratio. A decrease in the A/V ratio is associated with increased risk of stroke and myocardial infarction [9].

1.2 Problem Discription and motivation of the work

The objective of this thesis is to contribute the digital analysis of retinal images by segmentation and registration, which is a part of the field of retinal image analysis. Motivation behind this work is as follows:-

1. Due to worldwide growth of the aged population and pollution, there is increase in the eye disease patients, however the ophthalmic services are relatively decreasing, especially in rural areas and developing countries [10]. According to recent data of the World Health Organization (WHO) there are 37 million blind people and 124 million with low vision people presents in worldwide. The main causes of global blindness are glaucoma, corneal scarring, age-related macular degeneration, and diabetic retinopathy [11]. Diagnosis of these diseases are possible by examining the retinal blood vessel structure [11].

2. The everyday cost associated with eye-care provider's decisions and the ever increasing numbers of retinal patients to be reviewed are the major motivations for the adoption of automatic retinal image analysis [5]. The clinicians are costly experts, they need to optimize the time devoted to each patient. Moreover, the development of new imaging technology has resulted in rapidly increasing amounts of data collected as part of any specific retinal imaging exam. This amount of information is already exceeding the limit of clinician's ability to fully utilize it [5]. If we also take into account that clinicians are subjective, and their decisions suffer from inter- and intra-observer variability, the need for reliable computerized approaches to retinal image analysis is more obvious.

Therefore retinal blood vessels segmentation and registration is a prominent task for diagnosis of the retinal diseases. The assessment of retinal image has been extensively used by ophthalmologists for diagnosing the vascular and non vascular pathology. Examining the retinal blood vessel structure may reveal diabetes, hypertension, cardiovascular disease and stroke [11]. Retinal blood vessel segmentation can be done by manual or automatic. The manual segmentation of retinal blood vessels is a long and tedious task which also requires training and skill whereas automatic segmentation is fast. The automatic segmentation is commonly accepted by the medical community and it is the first step in the development of a computer-assisted diagnostic system for ophthalmic disorders.

Furthermore, the segmentation of retinal blood vessel structure is the most suitable representation for the retinal image registration since the vascular structure of the retina does not change except in a few diseases and contains adequate information for the identification of some anchor points. In addition, vessel structure can also be used as a landmark feature for image-guided laser treatment of choroidal neovascularization. Therefore, reliable methods for segmentation and registration of retinal images are required.

1.3 Thesis Objectives

The objective of the proposed work in this thesis is to identify the suitable probability distribution function (pdf) as a kernel to design a new matched filter approach that performs better retinal blood vessels segmentation result. Furthermore, in this thesis two segmented retinal images are registered by using the feature based registration technique.
The objectives of this thesis are as follows:

1. Comprehensive literature review and comparative study of various classical as well as state-of-the art methods for retinal blood vessels segmentation and feature based segmented retinal image registration techniques.

2. The design of a new and efficient approach for retinal blood vessel segmentation by using second derivative of Gaussian based matched filter.

3. The design of a new and efficient approach for retinal image segmentation by using Gumbel probability distribution based matched filter.

4. The design of a fast and efficient approach for segmented retinal image registration to identify the changes in vascular structure.

1.4 Organization of the Thesis

This thesis consists of six chapters. Outline of the thesis is as follows:

Chapter 1 presents background to discuss about the human eye, retina, related diseases, the motivation behind the thesis work, and objectives of this thesis. Finally concluding with an organization of this thesis.

Chapter 2 is organized in twofold literature review. The first fold presents a comprehensive literature review and comparative study of various classical as well as state-of-the art methods for retinal blood vessels segmentation, and second fold presents a comprehensive literature review of various classical as well as state-of-the art methods of intensity based and feature based retinal image registration.

Chapter 3 presents a novel extension of matched filter based retinal blood vessel segmentation approach, namely SDOG-MF. The SDOG-MF approach is based on second-order derivative of the Gaussian (SDOG) and local entropy thresholding. The proposed approach was able to identify thin retinal blood vessels as well as thick blood vessels. The proposed approach has been implemented on twenty retinal images taken from a test set of DRIVE database and twenty retinal images taken from STARE database. The segmented results of the DRIVE and STARE database is compared with hand-labeled ground truth images available in the respective database. The performance of the proposed approach is compared with some other existing standard methods for the same task available in the literature and it was found that the accuracy of proposed approach was good enough for retinal fundus images taken from a test set of DRIVE database, whereas the True Positive Rate (TPR) and False Positive Rate (FPR) was improved in case of retinal fundus images taken from STARE database.

Chapter 4 presents a novel matched filter approach with the Gumbel probability distribution function as its kernel. In the proposed approach, a customary Gaussian function used by prominent researchers [12], [13] and Cauchy probability distribution function used by [14] is replaced by Gumbel probability distribution function and achieve higher accuracy in retinal blood vessel segmentation. The reason to achieve the highest accuracy is due to better matching of gray scale cross-sectional profiles of retinal image and Gumbel pdf based kernel. The proposed matched filter with the Gumbel pdf as its kernel is compared with respect to the prominent Gaussian distribution function and Cauchy pdf based matched filter approaches and achieved the best performance. For the comparative analysis 20 retinal images have been selected from the test set of the DRIVE data set and STARE data set.

Chapter 5 presents a novel BRISK feature-based segmented retinal image registration approach because the BRISK framework is an efficient keypoint detector, descriptor and matching approach. The Gumbel pdf based matched filter approach is used for segmentation of source and target image because the Gumbel pdf based matched filter approach provided a better segmentation result with respect to other existing matched filter approaches. The performance of the proposed registration approach was demonstrated by evaluating the normalized cross correlation similarity measure for image pairs. On the basis of comparative analysis of the proposed approach with the SURF [15] and Harris partial intensity invariant feature descriptor based segmented retinal image registration approach, it was found that the performance of proposed approach is better in both aspects, the performance as well as computation time.

Chapter 6 presents conclusions of the thesis and summarize the main findings of this thesis work. This chapter also mention some possible future scope of the thesis.