CHAPTER 1
INTRODUCTION

Image analysis and computer vision techniques are increasing in prominence in all fields of medical sciences. These are especially pertinent to modern ophthalmology since it is heavily dependent on visually oriented signs. Dependence on manual observations may lead to improper judgments which ultimately affect the treatment planning. Exciting developments in image processing relevant to ophthalmology over the past 15 years includes the progress being made towards developing automated diagnostic systems for conditions such as diabetic retinopathy, age-related macular degeneration, retinopathy of prematurity, etc. The progress achieved in this field over recent years has significantly improved the type of medical care that is available to patients. The main focus of the research is to explore the various automated computational techniques that can be developed to identify the retinal pathologies and perform disease classification. These techniques can assist the physicians to evaluate their patients with advanced diagnostic tools in order to plan different forms of management and monitor the progress more efficiently than before. In this chapter, the significance of retinal image processing, anatomical structure detection and the various computational techniques are analyzed in detail to understand the objective of this research work. The organization of the thesis is also presented in this chapter.

1.1 SIGNIFICANCE OF RETINAL IMAGE PROCESSING

Human retinal images have gained an important role in the detection and diagnosis of many eye diseases for ophthalmologists. Some diseases such as glaucoma, diabetic retinopathy and macular degeneration are very serious for they can lead to blindness if they are not detected in time with perfection. Hence, retinal
image analysis has been a challenging research area that aims to provide techniques to assist in the early detection and diagnosis of many eye diseases. Conventional techniques are based on manual observation which is highly prone to error. Hence, the requirement of automated technologies for disease identification is significantly high.

Irrespective of the techniques used, the retinal images are mandatory for this application because the abnormalities are clearly observed in the retina than any other parts of the human eye. The appearance of blood vessels in the retina is a very important factor for diagnosing many kinds of pathologies. The retina is the only place where blood vessels can be directly visualized. The most retinal pathology is local in its early stages, not affecting the entire retina so that vision impairment is more gradual. However, early detection and treatment can slow or even halt the progression of the disease. The retinal portion of the human eye is normally captured using the camera. This image may be used for diagnosis, treatment and evaluation of various abnormalities in the eye.

1.2 SIGNIFICANCE OF ANATOMICAL STRUCTURE DETECTION

The retina of the human eye is made up of many internal anatomical structures. The significant anatomical structures present in the retina are the optic disc, the macula and the vessel network. The optic disc is a circular to oval white area measuring about 2 x 1.5 mm across in dimensions. The major blood vessels of the retina are radiated from the center of the optic disc. Another significant structure is the slightly oval-shaped, blood vessel-free reddish spot, the fovea, which is at the center of the area known as the macula by opthalmologists. The total retina is a circular disc of between 30 and 4 mm in diameter. Detection of these anatomic structures is fundamental to the subsequent characterization of the normal or disease states that may exist in the retina. The information of blood vessels, such as length,
width, tortuosity and branching pattern, can not only provide information on pathological changes but can also help to grade diseases severity or automatically diagnose the diseases. The detection of the optic disc is important to quantify retinal lesions, like the exudates lesions that characterize the diabetic macular edema. Moreover, optic disc parameters such as diameter can allow detection of other retina structures such as the fovea region. The presence of pathology and the extent of severity can be detected or quantified from the change of the basic shape of the anatomical retinal parts. Hence, prior knowledge about the anatomical structures is very important for automatic disease identification and classification.

A sample retinal image with specifications of the various anatomical structures is shown in Figure 1.1.

![Sample retinal image with anatomical structures](image)

Figure 1.1 Sample retinal image with anatomical structures

1.3 SIGNIFICANCE OF DISEASE IDENTIFICATION AND CLASSIFICATION

The disease identification is one of the important applications in the field of retinal image analysis. Much emphasis is given to this area since the complete treatment planning is based on the results of these disease identification techniques. The accuracy of the disease
identification techniques also must be significantly high since wrong identification may lead to fatal results. The convergence time for the results also must be sufficiently good besides being cost effective. For example, Diabetic Retinopathy (DR) diseases are the main cause of vision loss and their prevalence is set to continue rising. The lesions caused by diabetic retinopathy resemble the bright lesions caused by age related macular degeneration. So, it is very essential that the lesion types should be differentiated as they have different diagnostic importance and management implications. The screening of diabetic patients for the development of diabetic retinopathy can potentially reduce the risk of blindness in these patients. Currently, early detection has enabled laser therapy to be performed to prevent or delay visual loss and may be used to encourage improvement in diabetic control. Hence, current methods of detection and assessment of diabetic retinopathy are manual, expensive and require trained ophthalmologists.

Thus, novel techniques with the above mentioned features are highly necessary for the successful classification of the retinal pathologies. In this research work, four different and closely related eye pathologies like Choroidal Neo-Vascular Membrane (CNVM), Central Serous Retinopathy (CSR), Central Retinal Vein Occlusion (CRVO) and Non-Proliferative Diabetic Retinopathy (NPDR) are automatically identified and classified using Artificial Intelligence (AI) techniques. A brief description on these diseases is also given in this section.

CNVM is the development of new, abnormal vessels below the retina, the light-sensitive multi-layered tissue that lines the back of the eyeball. It can damage the important layers of the retina, compromising its ability to act as a barrier to the vascular layer below the retina, called the choroid. Once the retinal layers are damaged by diseases like macular degeneration, the choroid can produce new blood vessels (neovascularization) which grow up through the damaged layers and leak or bleed into the retina. Once this happens, the vision can become blurry, darkened or distorted. Choroidal neovascularization is a major cause of visual loss.

CSR is a visual impairment, often temporary, usually in one eye. The disorder is characterized by leakage of fluid in the central macula, which results in blurred or distorted vision. A blind or gray spot in the central vision is common, along with flashes of light.
People who need glasses may assume that the blurriness caused by CSR is simply a change in their prescription, and fail to have the condition assessed by a retinal specialist.

CRVO is estimated to be the second most common condition affecting blood vessels in the retina. Currently, no treatment exists for CRVO, in which a blood clot slows or stops circulation in a large vein within the eye’s light-sensitive retinal tissue. Reduced retinal circulation may lead to new blood vessel growth and blood vessel leakage, resulting in retinal tissue swelling, a common cause of vision loss from CRVO.

NPDR is a progressive pathology. Its severity is determined by the number and the types of lesions present on the retina. As a consequence there is a need to detect those lesions either for screening DR or for measuring its progression. Currently, lesion detection is performed manually. Automating this task would primarily be in terms of objectivity and reproducibility. Moreover, if screening or follow up becomes more widely accepted, automatic methods will be necessary to replace physicians in the time consuming process of lesion detection.

1.4 SIGNIFICANCE OF COMPUTATIONAL TECHNIQUES FOR RETINAL DISEASE IDENTIFICATION

An alternate to the conventional manual disease identification technique is the automated classification techniques. These techniques are mostly based on computer algorithms and can be used to analyze retinal images and compare those images with an archive of similar images with confirmed diagnoses of state of (or absence of) disease. The computational techniques employed for medical image analysis can be broadly classified into Artificial Intelligence (AI) based techniques and Conventional based techniques. Since AI techniques are more accurate, they are widely preferred over the Conventional techniques. Some of the common AI techniques are Artificial Neural Networks (ANN), Fuzzy theory, Optimization techniques, etc. The various significant aspects of these techniques are: (1) reliable diagnosis in comparatively lesser time than the reading center model; (2) inexpensive analysis and diagnosis enabling services in rural and third world communities; and (3) productive use of the
historical record of digital fundus imagery collected by the medical community. Even though these techniques are highly advantageous, the practical aspects of these techniques are not fully explored in the context of medical image analysis. These techniques can be used as stand-alone systems are can be used in conjunction with two or more techniques. The purpose of this research is to explore the applicability of these AI based techniques for retinal image analysis. Few novel hybrid techniques are also to be developed to enhance the performance of the conventional AI techniques. Finally, some of the Conventional techniques are also tested in this work to show the superior nature of the AI based techniques.

1.5 PROBLEM DEFINITION

The effects of the retinal pathologies on eyesight are mostly gradual in nature and hence early diagnosis and timely treatment can prevent loss of vision. Several diagnostic systems are available, with manual observation being the traditional technique followed in many parts of the world. Since human interception is time-consuming and highly prone to error, these techniques do not always guarantee a high degree of accuracy. Hence, automated techniques are highly essential for practical applications in the ophthalmologic field. Most of the automated systems are computer dependent and involve digital image analysis. Images of the retina are captured using a camera and further processing of the images is then performed by a computer to enable diagnosis of the disease. Diagnosis mainly involves the technique of image classification in which different abnormal images are grouped into several categories based on some similarity measures. These automated classification systems must yield high accuracy in minimal time. Earlier research has suggested that the application of automated systems based on Artificial Neural Networks (ANN) to satisfy the criteria of high accuracy in minimal time. However, the use of ANN in the field of ophthalmology has not been fully explored. There is scope for
improvement on the earlier research done in the area of retinal disease identification using ANN.

In this research work, several combinations of AI based techniques are developed for retinal disease identification with an objective to achieve high accuracy within less convergence time. The results of these techniques are also compared with the conventional techniques. These techniques are tested on a sufficiently large database collected from the hospitals. The performance measures of these techniques are further analyzed to verify the capability of the proposed approaches for retinal disease identification.

1.6 OBJECTIVES OF THE RESEARCH WORK

- To automatically classify the abnormal retinal images into four different categories using soft computing techniques
- To explore the application of conventional Artificial Neural Networks (ANN) for retinal disease identification.
- To apply Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) for feature selection in retinal image analysis.
- To develop unconventional hybrid soft computing techniques for retinal image classification.
- To analyze the classifiers in terms of Classification Accuracy, Sensitivity, Specificity, Positive Likelihood Ratio and Negative Likelihood Ratio.

1.7 PROPOSED METHODOLOGY

The framework for solving the problem defined above is shown in Figure 1.2. Several procedural steps are followed to achieve the objective of this research work. Several works also have been done with each individual module of this system. Initially, the image database is formed by collecting abnormal retinal images from
the hospitals. These input images are mostly in the RGB format. An extensive pre-
processing procedure is employed on these images to enhance the contrast between 
the background and the region of interest of the image. Further, several features are 
extracted from these images for assisting in image classification. Three set of 
features are used in this work. The first set of features is area, perimeter and 
circularity which are purely based on the anatomical structures of the retinal image. 
The second set of features is mean, standard deviation, skewness, kurtosis, energy 
and entropy which are based on the first order histogram. The third set of features is 
contrast, inverse difference moment, correlation, variance, cluster shade, cluster 
prominence and homogeneity which are based on the Gray Level Co-occurrence 
Matrix (GLCM).

All the extracted features do not guarantee high accuracy. Hence, the feature 
selection process is further used to select the optimal feature set which can enhance 
the overall accuracy of the system. Genetic Algorithm (GA) and Particle Swarm 
Optimization (PSO) are the two optimization algorithms used in this work for feature 
selection. The features obtained from these feature selection algorithms are further 
used for retinal image classification.

Initially, the image classification system is tested with the conventional 
techniques. These techniques are mostly non-AI techniques. Secondly, the retinal 
images are classified using the conventional AI techniques. Both ANN and fuzzy 
techniques are implemented as representatives of AI systems. Thirdly, hybrid 
systems such as the combination of ANN and GA, ANN and PSO, etc. are developed 
for the image classification system. Finally, a performance enhanced modified ANN 
is developed and tested with the abnormal images.

An extensive comparative analysis is performed among these classifiers in 
terms of classification accuracy and the time requirement for convergence. Thus, this 
research work aim to bring out the hidden characteristic features of AI based
classification techniques for retinal imaging applications. Few modified techniques are also to be implemented to enhance the performance of the conventional AI systems.

Figure 1 Block diagram of proposed work
1.8 ORGANIZATION OF THE THESIS

The rest of the thesis is organized as follows.

A comprehensive review of literature on image pre-processing, feature extraction, feature selection and retinal image classification are presented in Chapter 2. The literature survey on ANN techniques and fuzzy based techniques for image classification are also included in this chapter.

Chapter 3 provides the detailed information on the image database used along with the techniques used for image pre-processing and feature extraction. The experimental results of each stage are also discussed in this chapter.

Chapter 4 describes the methodology of retinal image classification using the conventional classification techniques. In this chapter, the various aspects of Minimum Distance Classifier and the Bayesian Classifier are analyzed along with the experimental results.

Chapter 5 discusses the application of conventional AI techniques for image classification. ANN techniques such as Back Propagation Neural networks (BPN), Radial Basis Function networks (RBF), Self Organizing Maps (SOM), Counter Propagation Neural networks (CPN) and fuzzy techniques such as Fuzzy classifier are discussed in this chapter.

Chapter 6 covers the hybrid AI techniques for retinal image classification. The techniques discussed in this chapter are the combination of GA with BPN, SOM and fuzzy classifier and the combination of PSO with BPN, SOM and fuzzy classifier.

Chapter 7 presents the modified ANN which is one of the significant contributions of this research work. A modified SOM is developed and tested with the same set of retinal image database.

The experimental results of each module are analyzed in the respective chapters along with the comparative analysis. The final chapter gives the summary of work done, contribution of the work, limitations and scope for further work.