Introduction

Chapter 1

1.1 Title: “Design and Development of New Wavelet Filter for Detection and Grading of Non-Proliferative Diabetic Retinopathy Lesions”

1.2 Objectives:
1. Analysis of Fundus Images
2. Design New Wavelet Filter
3. Detection of different types of non-proliferative diabetic retinopathy lesions
4. Classification of Diabetic Retinopathy lesions using Neural Network
5. Grading level of Non-proliferative Diabetic Retinopathy

1.3 Introduction:
The retina is a layered tissue lining the interior of the eye that enables the conversion of incoming light into a neural signal that is suitable for further processing in the visual cortex of the brain. It is thus an extension of the brain. The ability to image the retina and develop techniques for analyzing the images is of great interest. As its function requires the retina to see the outside world, the involved ocular structures have to be optically transparent for image formation. Thus, with proper techniques, the retina is visible from the outside, making the retinal tissue, and thereby brain tissue, accessible for imaging noninvasively (Fig. 1.1). Because the retina’s function makes it a highly metabolically active tissue with a double blood supply, the retina allows direct noninvasive observation of the circulation [1].
We proposed a new wavelet filter (rrm) for extraction of non-proliferative diabetic retinopathy (NPDR) lesions such as microaneurysms, hemorrhages, hard exudates and retinal blood vessels.

Non-proliferative diabetic retinopathy, previously called background retinopathy, is the initial stage of diabetic eye disease. Microscopic changes arise in the blood vessels of the eye in non-proliferative disease; however, the changes characteristically do not produce symptoms and are not visible to the naked eye. Non-proliferative disease progresses from mild to moderate to severe [2].

Non-proliferative diabetic retinopathy is initially characterized by Microaneurysms (microscopic blood-filled bulges in the artery walls) which may burst and leak into the retina. Tiny spots or dots of blood may accumulate in the retina, but they usually do not produce noticeable symptoms in the early stages of the disease. As the disease progresses, hard exudates (accumulations of fluid that has leaked from blood
vessels), abnormalities in the growth of microscopic blood vessels in the retina, and bleeding from the veins that feed the retina may occur [2].

![Figure 1.2: Anatomy of Eye](image)

While non-proliferative diabetic retinopathy is not itself a sight-threatening condition, it can trigger macular oedema or macular ischaemia, which are other forms of diabetic retinopathy that may cause rapid vision loss at any stage of non-proliferative disease. In addition, the vascular changes that occur in non-proliferative retinopathy lead to retinal ischaemia (lack of blood flow to the retina) and trigger progression to sight-threatening proliferative disease. As the severity of non-proliferative retinopathy increases, the risk of developing sight-threatening proliferative diabetic retinopathy also increases [2].

Artificial neural networks (ANNs) are computational models inspired by an animal's central nervous systems (in particular the brain) which is capable of machine learning as well as pattern recognition. Artificial neural networks are generally presented as systems of interconnected "neurons" which can compute values from inputs. For example, a neural network for diabetic retinopathy lesions recognition is defined by a set of input neurons may be activated by the pixels of an input fundus image. The activations of these neurons are then passed on, weighted and transformed by a function determined by the network's designer, to other neurons. This process is
repeated until finally, an output neuron is activated. This determines which lesions
was present on that fundus image. Like other machine learning methods, systems that
learn from data, neural networks have been used to solve a wide variety of tasks that
are hard to solve using ordinary rule based programming, including computer vision
and diabetic retinopathy lesions recognition.
Non-proliferative diabetic retinopathy is classified in three categories like
- **Mild**: Indicated by the presence of at least one microaneurysm
- **Moderate**: Includes the presence of hemorrhages, microaneurysms, and hard
  exudates
- **Severe**: Many more blood vessels are blocked, depriving several areas of the
  retina with their blood supply. These areas of the retina send signals to the body to
grow new blood vessels for nourishment [3].

Diabetic retinopathy is the name given to the changes in the retina, which occur over
a period of time in diabetics. The retina is the back part of the eye and is made up of
cells, which are sensitive to light.

It is fed by a network of blood vessels and it is changes in these which cause the
difficulties with vision. The walls of the blood vessels become fragile and then start
to break, leaking blood around them. Sometimes, before the walls actually break, the
weakened area can be seen, by the person who examines the eye, to have ballooned
out. These are called micro-aneurysms. If these break, the amount of blood which
leaks out is fairly small, and the only symptoms may be a few areas of blurring or
floating spots in front of the eyes. These may well disappear without treatment.
Later the blood vessels may stop carrying blood permanently, and the cells in the retina will die from lack of nourishment. This kind of loss of sight is gradual but at the present time, it is permanent. When old blood vessels close down, new but abnormal ones will grow to take their place. They are unable to nourish the retina properly, and may grow into the transparent inner part of the eye, and further affect vision [4].

1.3.1 Diabetic Retinopathy: The most serious diabetic eye condition involves the retina and is called diabetic retinopathy [4].

1.3.2 Background Diabetic Retinopathy: This condition is very common in people who have had diabetes for a long time. Your doctor may be able to see abnormalities in your eyes, but there is no threat to your sight. There are two types of diabetic retinopathy, which can damage your sight. Both involve the fine network of blood vessels in the retina. They are described below [4].
1.3.3 **Maculopathy:** This happens when the blood vessels in the retina start to leak. If the macula is affected, you will find that your central vision gradually gets worse. You may find it difficult to recognize people's faces in the distance or to see detail such as small print. The amount of central vision that is lost varies from person to person. However the vision which allows you to get around at home and outside (navigation vision) will be preserved. It is very rare for someone with maculopathy to lose all their sight [4].

1.3.4 **Proliferative Diabetic Retinopathy:** Sometimes diabetes can cause the blood vessels in the retina to become blocked. If this happens then new blood vessels form in the eye. This is natural way of trying to repair the damage so that the retina has a new blood supply. Unfortunately these new blood vessels are weak. They are also in the wrong place growing on the surface of the retina and into the vitreous jelly. As a result these blood vessels can bleed very easily and cause mark tissue to form in the eye. The scarring pulls and distorts the retina. When the retina is pulled out of position this is called retinal detachment [4].

- This condition is rarer than background retinopathy and is more often found in people who have been insulin dependent for many years.
- The new blood vessels will rarely affect vision, but their consequences, such as bleeding or retinal detachment can cause vision to get poorer suddenly.
- Eyesight may become blurred and patchy as the bleeding obscures part of vision.
- Without treatment, total loss of vision can happen in proliferative retinopathy.
- With treatment most sight-threatening diabetic problems can be prevented if caught early enough.

1.4 **Workflow:**

For detection of non-proliferative diabetic retinopathy we use digital image processing, symlet wavelet and proposed new wavelet filter (rrm). Non-proliferative diabetic retinopathy categorized in four lesions such as microaneurysms,
hemorrhages, exudates and Neovascularization. In this research work we done eight experiments tasks such as.

1.4.1 Extraction of Mask
1.4.2 Removal of Optic Disc
1.4.3 Design New Wavelet Filter (rrm)
1.4.4 Extraction of Microaneurysms
1.4.5 Extraction of Hemorrhages
1.4.6 Extraction of Exudates
1.4.7 Extraction of Cotton Wool Spots
1.4.8 Extraction of Retinal Blood Vessels

Figure 1.4: Workflow of design new wavelet filter for detection non-proliferative diabetic retinopathy lesions.
1.4.1 Extraction of Mask:

To extract the mask apply digital image processing by extracting red channel from color fundus image. Then apply threshold function to extract the mask of all retinal fundus image.

1.4.2 Removal of Optic Disc:

The removal of optic disc is very important because in non-proliferative diabetic lesions one of the lesions called exudates are having same structure like optic disc to avoid these ambiguity we have removed the optic disc from all fundus images. To remove optic disc, extract green from color fundus image afterwards apply complement function followed by intensity transformation function.

1.4.3 Design New Wavelet Filter (rrm):

In MATLAB wavelet toolbox provides large number of the most commonly used wavelet families. Using Wavelet Manager (wavemngr) we can design new wavelet and add it on existing wavelet family. The toolbox allows us to define new wavelets for use with both the command line functions and the graphical interface tools.

1.4.4 Extraction of Microaneurysms:

Microaneurysms are the first clinically detected lesions. It is tiny swelling in the wall of a blood vessel. It appears in the retinal capillaries as a small, round, red spot. Located in the inner nuclear layer of the retina [5]. To extract the microaneurysms, green channel separation is done afterward apply histogram equalization then proposed wavelet is applied of retinal fundus image to extract the microaneurysms.
1.4.5 Extraction of Hemorrhages:

Hemorrhages are one of the first signs of diabetic retinopathy and are also prominent in other ocular disease. Small round dot hemorrhages that are related to microaneurysms and indistinguishable from microaneurysms in color fundus images, through the flame shaped and blotch (cluster) hemorrhages whose names describe their appearance, to the larger boat shaped hemorrhages [6]. For extraction of hemorrhages, green channel separation is done afterwards apply CLAHE techniques followed by threshold and at the last apply proposed wavelet filter (rrm) for the extraction of hemorrhages.

1.4.6 Extraction of Exudates:

Exudates are one of the major signs of diabetic retinopathy which is a main reason of blindness that could be prevented with an early screening process. Pupil dilation is required in the normal screening process but this affects patient’s vision. For extraction of exudates, extract green channel then intensity transformation function followed by threshold and lastly apply proposed wavelet filter (rrm) to extract the exudates.

1.4.7 Extraction of Cotton Wool Spots:

Cotton wool spots are caused by damage to nerve fibers and are a consequence of accretions of axoplasmic material within the nerve fiber layer. For extraction of cotton wool spots, extract green channel then intensity transformation function followed by threshold and lastly apply proposed wavelet filter (rrm) to extract the cotton wool spots.

1.4.8 Extraction of Retinal Blood Vessels:

Neovascularization cause the blindness because all retina get nourishes with the blood vessels. Retinal blood vessels extraction is very important because after extraction we calculate the diameter of vessels to see whether the blood...
vessels are normal or not, the normal diameter of overall blood vessels is >25 mm to 30 mm. To extract the retinal blood vessels, extract green channel then intensity transformation function afterwards histogram equalization, morphological operations, median filter followed by threshold and at last apply proposed wavelet filter for extraction of retinal blood vessels.

1.5 Significance of Work

Diabetes, which can be characterized as a chronic increase of glucose in the blood, has become one of the most rapidly increasing health threats worldwide. Diabetic retinopathy, the most common diabetic eye disease, occurs when blood vessels in the retina change. Sometimes these vessels swell and leak fluid or even close off completely. In other cases, abnormal new blood vessels grow on the surface of the retina. For Diabetic patient regular eye check-up and screening is required. Fundus image is taken to view the abnormalities. At times lesions are not visible through fundus image, doctor’s recommends angiography. However Angiography is not advisable in certain conditions like if patient is of very old age, if patient is a child, if patient is a pregnant woman, if patient is suffering from hypertension, stroke, or if patient has undergone some major surgery. Sometimes even a clinically healthy person can be hypersensitive to the dye and may experience dizziness or faintness, dry mouth or increased salivation, hives, increased heart rate, metallic taste in mouth, nausea and vomiting, sneezing. In this proposed algorithm, angiography can be avoided because NPDR lesions are detected at early stage.

In this proposed algorithm we have detect the non-proliferative diabetic retinopathy lesions such as microaneurysms, hemorrhages, exudates and blood vessels. Also we design graphical user interface tool for the ophthalmologist for the detection of non-proliferative diabetic retinopathy lesions.

Also we proposed new wavelet filter for extraction of NPDR lesions and add this wavelet filter into the stack of wavelet family.
1.6 Summary of Chapters

**Chapter 2:** Non-proliferative diabetic retinopathy (NPDR) is the initial stage of diabetic retinopathy. With this condition, damaged blood vessels in the retina begin to leak extra fluid and small amounts of blood into the eye. Non-proliferative diabetic retinopathy is mainly categorized into three categories, such as Mild, Moderate and Serve. In this chapter, the researchers are explain how they have detected the non-proliferative diabetic retinopathy lesions. Such as microaneurysms, hemorrhages, exudates and blood vessels using different kinds of image processing techniques and multi resolution analysis using wavelet approach. For result analysis authors have used the online databases like STARE, DRIVE, DiaretDB0, DiaretDB1 RetiDB, Messidor and also local databases from ophthalmologist. For classification, authors have used some classification techniques such as, neural network models like artificial neural network (ANN), multi-layer perceptron (MLP) are used for classification and for grading of non-proliferative diabetic retinopathy lesions. Also receiver operating characteristic curve is used for calculating the performance analysis of the algorithm.

**Chapter 3:** In this methodology chapter, we discuss about the collection of databases with its detail. Also we discuss about the proposed wavelet filter (rrm) for extraction of non-proliferative diabetic retinopathy lesions. Total five databases we have collected. SASWADE, STARE, DRIVE, DIARECTDB0 and DIARECTDB1 with total 856 fundus images. After collection of fundus image databases, we have apply some digital image processing techniques, proposed wavelet filter (rrm) and symlet wavelet for extraction of lesions. Non-proliferative diabetic retinopathy is categorized into five lesions such as, microaneurysms, hemorrhages, exudates and neovascularization (abnormal blood vessels). Neovascularization is very dangerous lesion because it directly causes the blindness to the patient, for identification of neovascularization we require some parameters of retinal blood vessels like area of blood vessels, diameter, thickness, length etc. After feature extraction of non-proliferative diabetic retinopathy, classification is done. For classification, K-Means clustering were used. After classification of lesion, grading is done. For grading,
artificial neural network were used. After classification and grading of non-proliferative diabetic retinopathy lesions, performance analysis is done using receiver operating characteristic (ROC) curve. And at the last, statistical techniques is done for calculating the correlation of the non-proliferative diabetic retinopathy’s features.

Chapter 4: In this experimental work chapter, all experimental results is discussed like mask separation, optic disc removal, extraction of microaneurysms, extraction of hemorrhages, extraction of exudates, extraction of cotton wool spots and extraction of retinal blood vessels and its statistical parameters (area, length, thickness, diameter, bifurcation points and tortuosity). After extraction of non-proliferative diabetic retinopathy lesions classification is done using k-means clustering and statistical techniques (mean, variance, standard deviation and correlation). For grading of the NPDR lesions, artificial neural network is used. The proposed research work is got 98 % result.

Chapter 5: In conclusion and future scope chapter, we discuss the conclusion of proposed research, its limitations and future scope.

Summary:

In this chapter we explain introduction of retina and its features then anatomy of human eye. Also emphasis on diabetic retinopathy, non-proliferative diabetic retinopathy and its lesions. Afterwards, we explicate workflow for extraction of non-proliferative diabetic retinopathy lesions and at the last we describe significance of the proposed research.
References:


