Chapter 3

RETINAL BLOOD VESSELS EXTRACTION

This chapter describes a novel method for extracting healthy blood vessels from fundus images using morphological operations. After size normalization green channel component of the RGB fundus image is extracted. Median filtering is applied to denoise followed by adaptive histogram equalization to enhance the features to be extracted. Then a series of morphological operations and segmentation operations are applied to extract the blood vessels. The extracted blood vessels are verified by an expert for its correctness.

3.1 Introduction

People with untreated diabetes are 25 times more at risk for blindness than the general population. The longer a person has had diabetes, the higher the risk of developing diabetic retinopathy. When affected with DR the healthy retinal blood vessels, that nourish the eye, get damaged. In order to grade diabetic retinopathy the ophthalmologists consider the area occupied by healthy blood vessels. The area occupied by the healthy blood vessels is large in a normal eye compared to the eye affected by DR. Hence, it is essential to estimate the area occupied by blood vessels to detect and grade DR.

The process of separating the portions of retinal images that are vessels from rest of the image is known as vessel extraction. This task is complicated due to factors such as poor contrast between vessels and background, presence of noise, varying levels of illuminations and contrast across the image, physical inconsistencies of vessels [50-54] and presence of pathologies. All these factors yield different results. Different methods yield distinctly different results and even the same method will yield different results for images taken from the same patient in a single session. These differences become significant for images taken at different points in time as they could be mistaken as changes. The methods used to determine the vessels boundaries should strive to lessen the frequency and severity of these inconsistencies.
There are various reasons for detecting blood vessels, ranging from a need to identify vessel locations to aid in reducing false-detection of other lesions, to detecting the vessel network to establish their geometrical relationships or identifying the field-of-view of the retina, through to accurate delineation of the vessels for quantitative measurement of various parameters such as width, branching ratios and tortuosity and for identifying vessel features such as venous dilation and arteriolar narrowing.

In [55-57], algorithms to delineate the network in fluorescein retinal images are presented. In [58-60], algorithms that work on color fundus images are presented. Matched filtering approach followed by threshold probing is presented in [61, 62]. The algorithms that use mathematical morphology are presented in [63, 64]. Various other methods including multi threshold probing [65], wavelet analysis [58] and many more methods [67-70, 89].

From the literature it is clear that various blood vessel extraction algorithms are designed but very few have made an attempt to extract blood vessels in order to grade diabetic retinopathy. This motivated us to work towards extraction of only healthy blood vessels from the fundus images. Since morphological operations have proven their ability in extracting shape based features [69], we use them in designing blood vessel extraction algorithm.

3.2 Methodology

Morphological operations and Segmentation: Morphological operations are applied to the pre-processed image. First, the morphological opening is performed with a ball shaped structuring element of size 8, the size being chosen empirically. Then image subtraction is performed between opened image and contrast enhanced image resulting in elimination of optic disc.

The canny operator [72] is used to find the edges of the structural parts of retina and pathologies such as microaneurysms and exudates. Thresholding with respect to size is done to eliminate non-essential objects.

Morphological Reconstruction: Some of the blood vessels present in optic disc are lost as a part of optic disc elimination. Hence to get back the information about the lost blood vessels morphological reconstruction is performed. A mask of 90-pixel diameter is created around
the brightest pixel in the image. This mask is used as a marked image to reconstruct the blood vessels in optic disc. A disk shaped structuring element of size 6 is used in reconstruction.

### 3.3 Algorithm

Morphological operations are applied to the pre processed input image to extract blood vessels followed by optic disk detection and elimination [figure 15]. Empirically, ball shaped structuring element of size 8 is used to detect the blood vessels. Due to elimination of optic disk, the blood vessels in it are also lost; hence morphological reconstruction is applied to retrieve the lost blood vessels. At this stage, segmentation is performed to eliminate other features like microaneurysms and exudates. Finally, the area of the blood vessels is calculated.

![Figure 15: Block Diagram for Blood Vessel Extraction.](image)

**Algorithm:**

**Input:** RGB Fundus image.

**Output:** Binary image with blood vessels extracted and count representing total area occupied by healthy blood vessels.

**Method:**

Step 1: Pre processing

i. Normalize the image with respect to size.

ii. Extract green channel of the RGB image.

iii. Apply adaptive histogram equalization thrice, to enhance the image.
Step 2: Morphological operations

   i. Perform opening with ball shaped structuring element of size 8.
   ii. Perform erosion with disk shaped structuring element of size 6.
   iii. Perform dilation with disk shaped structuring element of size 6.

Step 3: Optic disc Detection and Elimination: Perform image subtraction on enhance image and opened image to eliminate the optic disc.

Step 4: Reconstructing blood vessels in optic disc

   i. Find the brightest pixel in the image.
   ii. Construct a mask of 90 pixels in diameter.
   iii. Perform morphological reconstruction using the mask and disk shaped structuring element of size 6.

Step 5: Segmentation

   i. Canny operator is used to detect the edges.
   ii. The small circular objects (Microaneurysms and exudates) are subjected to imfill().
   iii. The filled circular objects are removed using size thresholding.

Step 6: Area Calculation: The area is computed by count the number of ON pixels in the final resultant binary image.

3.4 Experimental Results

The proposed method of blood vessel extraction is experimented on fundus eye images. A total of 100 images of dimension 4288X2848 are used to evaluate the performance of the proposed method [1.5.1]. The performance has been evaluated by the experts.

In normal case, retina contains healthy blood vessel network [figure 16{1-3}] hence the area occupied by the blood vessels is more. The area of blood vessels in retina affected by mild NPDR [figure 16{4-5}] is less as compared to area of blood vessels in normal retina. In case of moderate [figure 17{1-2}] NPDR, the area occupied is less than normal/mild but more than sever NPDR [figure 17{3-5}] affected retina.
Figure 16: Result of Blood Vessel Extraction from Normal (1-3) & Mild NPDR (4-5) Images
Figure 17: Result of Blood Vessel Extraction from Moderate (1-2) & Mild NPDR (3-5) Images
3.5 Summary

Area occupied by the healthy blood vessels is one of the criteria used by ophthalmologist in grading diabetic retinopathy. An efficient method for extracting blood vessels from fundus images using morphological operations is described. Morphological operations are used to extract blood vessels. Experiments have been carried out on 100 fundus images collected from Karnataka Institute of Diabetology, Bangalore. The Proposed method aimed at extracting healthy blood vessels from fundus images has yielded encouraging results. The results have been verified by the experts for its correctness. The novelty or the major contribution of the proposed method is that it extracts only healthy blood vessels and discards the damaged vessels based on the diameter or width of the vessels.