CHAPTER 4

STATISTICAL ANALYSIS FOR THE EXTRACTION OF MORPHOLOGICAL FEATURES FROM RETINAL IMAGES

4.1 BACKGROUND

Diabetic retinopathy is the most common sight threatening disease which when untreated leads to vision loss. A reversal is not possible in many cases. The damaged blood vessels as a result of diabetic retinopathy leak extra fluid and small amount of blood into the eye. Macular edema is the increase in fluid called exudates in macula. It is the main cause of vision loss and its continued prevalence is predicted. As the disease progresses the amount of exudates also increases; the blood vessels in the retina close and prevent blood flow in the eye. This situation leads to the development of new blood vessels to supply blood to the blocked area.

The normal retinal fundus image and the image with annotated Exudates are shown in Figure 4.1. The Exudates are exhibited as spatially random yellowish or whitish patches of varying shapes, sizes and localities. These are the visible sign of diabetic retinopathy and a major cause of visual loss. Detection of Exudates by ophthalmologists is a difficult process as they have to spend a considerable time on manual analysis [79]. In addition, manual detection involves utilization of chemical dilation material which takes more time with harmful side effects on the patients. There is an imperative need for a digital image acquiring technology to help minimizing the side effect flowing from such screenings [80, 81]. This technology allows the scientists to utilize the ‘state-of-the art’ image processing techniques which automate the detection of abnormalities.

Literature shows availability of, several methods for exudate detection. In addition, there are basically three problem solving approaches. These approaches are based on thresholding and region growing [43, 46, 47], clustering techniques [36, 39-41, 43], and a mathematical morphological approach [22-34].
The major problem in the thresholding and the region growing approaches is the low quality of the images which may hamper separation or classification of bright and dark lesions. This fact occurs due to the difficulty involved in the selection of region seedpoints, threshold values, and in automatic establishment of stopping criteria for the iteration. Despite the capability of the clustering techniques in the detection of exudates to produce results with good accuracy or success rate, these methods are dependent on the identification of the number of clusters, the choice of the elements set input and the choice of the clustering method. Some of the results of the clustering step were very promising. However, the final results obtained were not satisfactory. This fact may occur due to inefficiency of the process of exclusion of false candidates. Similarly the problems in the morphological analysis are the determination of the background image that shows susceptibility to non-uniform illumination and still depends on the optic disc and blood vessel detection.

The major challenges for extraction of Exudates are:

a) The accurate segmentation of the Exudates is difficult because of its un-defined shape and size.

b) To distinguish them from other regions in the retina such as optic disc and other abnormal signs such as hemorrhages or microaneurysms since they are similar in shapes and colors.

Hence, in this work, automatically, the retinal images are classified as exudates and non-exudates using disease based features and statistical features extracted from the images in the assessment of diabetic retinopathy.
Figure 4.1 Sample retinal fundus images of (a) Normal and (b) Diabetic retinopathy subjects
4.2 STEPS INVOLVED TO DETECT DIABETIC RETINOPATHY

4.2.1 Data Description

This study was performed on the same samples of 60 Indian subjects whose age ranged from 50-85 years as mentioned in Chapter-3, section-3.2.1. The digital image of the affected eye was acquired using a digital fundus camera in combination with Visupac image management software system. The acquired digital fundus images were of size 640×480 and stored on the local hard drive of a computer system for further analysis.

Then the stored images were visually analyzed by an experienced ophthalmologist and grouped into following:

Group I: Normal
Group II: Diabetic Retinopathy

4.2.2 Fundus Image Analysis

The preprocessing of the digital fundus images consists of the following three stages:

(i) Color normalization
(ii) Edge enhancement
(iii) Color space conversion

Digital fundus image was pre-processed using the procedures detailed in Chapter-3, Section-3.2.2. The next step was binarising the pre-processed fundus images. The binarisation process was done by setting an empirical threshold value of 0.78. The binary image contains many objects such as blood vessels, optic disc, exudates and any unwanted noises in the retinal region. Based on removing the following contents from the binary image exudates contents were retained (detailed in Chapter-3, Section-3.2.2.4):...
- The blood vessels do not contain much information about exudates
- Optic disc, which is the entry region of blood vessels and optic nerve to the retina
- Borders of the retinal region

Finally, the following morphological features such as area, number of objects, eccentricity, extent, orientation, convex area of polygon and solidity (detailed in Chapter-3, Section-3.2.2.5) were extracted from the binary image which contains only information about small objects:

4.2.3 Statistical Analysis

The demographic features and extracted morphological features were analysed using SPSS software package version 17.0 (SPSS Inc., Chicago, USA). The measured values in each subgroup were compared using a student’s t-test. The data represented were represented in mean ± SD.

4.3 RESULTS

The result of the proposed exudates detection process has been depicted in Table 4.2. The system achieved 93% segmentation accuracy with the ground truth results.

All retinal fundus images were acquired using a standard protocol. For each image the ground truth result was collected from two glaucoma experts with more than ten years of experience. Then the quantitative evaluation of the proposed algorithm has been carried out using these ground truth results. Out of the 60 studied subject, 43% (26/60, mean ± SD age = 53.2± 8.4 years) belonged to normal group and 57% (34/60, mean ± SD, age = 57.2± 11.4 years) belonged to DR group, based on the ground truth classification. The retinal fundus images of the normal and DR samples are displayed in Figure 4.1. The feature extraction technique detailed in the methodology section has been applied to each fundus image and results obtained are depicted in the Table 4.1. The Table 4.1 also contains the
details about the features extracted using the hand drawn ‘ground truth’ results along with the demographic as well as anthropometric parameters. The age and Body Mass Index (BMI) values were not showing any significant variation between normal and DR group. Whereas, the morphological features extracted from digital fundus images using the ground truth method as well as automatic image analysis algorithm exhibited significant (p<0.001) difference between the groups, i.e. the mean intensity value displayed significance increment in the DR group when compared to the normal group. The results of various steps involved in the segmentation of exudates region are shown in Figure 4.2. The performances of the proposed exudate extraction technique with the ground truth method have been compared. To assess the area overlapping between the computed regions and the ground truth results, the pixel-wise precision and recall values are computed. These are defined as follows in Equation 4.1 and 4.2:

\[
\text{Precession} = \frac{TP}{TP + FP} \quad (4.1)
\]

\[
\text{Recall} = \frac{TP}{TP + FN} \quad (4.2)
\]

Where, TP, FP and FN are a number of true positive, false positive and false negative pixels respectively. Finally, traditional F-score and segmentation accuracy are computed, using the following Equation 4.3 and 4.4:

\[
F = \frac{\text{Precession} \times \text{Recall}}{\text{Precession} + \text{Recall}} \quad (4.3)
\]

\[
\text{Accuracy} = \left[ 1 - \frac{\text{Number of misclassified pixels}}{\text{Total pixels}} \right] \quad (4.4)
\]
### Table 4.1
Range of the morphological features extracted from the retinal images

<table>
<thead>
<tr>
<th>Variables / groups</th>
<th>Normal group (n = 26)</th>
<th>DR group (n = 34)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic and anthropometric parameter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>53.2 ± 8.4</td>
<td>57.2 ± 11.4</td>
<td>0.152</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.3 ± 5.3</td>
<td>29.2 ± 7.4</td>
<td>0.184</td>
</tr>
<tr>
<td><strong>Retinal image parameters extracted by ‘ground truth’</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean intensity (gray)</td>
<td>0.52 ± 0.12</td>
<td>0.82 ± 0.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean area (%)</td>
<td>50.5 ± 14.2</td>
<td>12.7 ± 8.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Number of objects</td>
<td>40.7 ± 11.4</td>
<td>17.3 ± 4.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Solidity</td>
<td>0.18 ± 0.06</td>
<td>0.71 ± 0.01</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Retinal image parameters extracted by the ‘automated system’</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean intensity (gray)</td>
<td>0.59±0.18</td>
<td>0.79±0.12</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean area (%)</td>
<td>46.6±11.4</td>
<td>14.2±9.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Number of objects</td>
<td>42.3±12.2</td>
<td>15.6±4.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Solidity</td>
<td>0.21±0.11</td>
<td>0.76±0.03</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

# Normalized the intensity values between 0 and 1

DR-Diabetic Retinopathy

### Table 4.2
Result of exudates detection technique when compared with the ground truth method

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precession</td>
<td>0.931</td>
</tr>
<tr>
<td>Recall</td>
<td>0.893</td>
</tr>
<tr>
<td>F-score</td>
<td>0.882</td>
</tr>
<tr>
<td>Segmentation accuracy (%)</td>
<td>92.62</td>
</tr>
</tbody>
</table>
Figure 4.2 Steps involved in the segmentation process. (a) input fundus image, (b) normalized result of (a), (c) segmented image, (d) border of (a), (e) extracted vessel image, (f) segmented optic disc, (g) exudates region (c - (d + e + f)), (h) superimposed image
4.4  DISCUSSION

The World Health Organization predicts that in the next 25 years, the amount of individuals with diabetes across the globe will become double [82]. About 50% of the individuals who are suffering from diabetes across the globe do not undergo any type of eye examination [9]. This is due to lack of awareness on one side and on the other side is a problem in the conventional diagnosis, and procedures such as computational time as well as cost. Hence, there is an immediate need of developing a mass screening tool which would work on bulk databases with affordable cost.

The proposed computer aided detection system is advantageous on account of its fast diagnosis, utilization of widely available fundus images and simple protocol. The fundamental concept behind the proposed system was the extraction of morphological parameters of exudate regions by subtracting blood vessels, optical disc and outer border of the retinal region. The extracted morphological parameters in exudate region indicate the subtle changes in the normal and DR group. It can be clearly seen from Table 4.1 that all these morphological parameters shows significant difference in value for normal as compared to the DR class (p<0.001). In the normal images, the intensity values in the segmented region were observed as low (Table 4.1), whereas it was high for DR images due to the presence of hard exudates. The similar kind of variations was observed when the energy values extracted using wavelet based approach [83]. Similarly, the morphological parameters extracted from digital X-ray images for classification of osteoporosis from the normal group also displayed significance at p<0.001 [63].

The age and BMI values did not show any kind of significance between normal and DR group. Hann et al have explored the structural characteristics of the morphological features from digital fundus image and found out that the amount of pixels covering exudates could be used as a metric for the degree of the disease [84]. Similarly, in the present study, the result in terms of accuracy (93%) depicted in Table 4.2 was typical over all images with the number of exudates found agreeing well visually. The obtained result showed the potential for tracking the progress of DR.
Similarly, the other parameters such as traditional F-score, precession and recall values were 88.2, 93.1 and 89.3% respectively.

4.5 CONCLUSION

Automatic methods for screening exudates for DR diagnosis have been developed based on image processing methods which utilized color component, morphology and intensity values in retinal digital fundus images. The extracted morphological parameters exhibited significant differences between normal and DR groups at p<0.001, whereas, the age and BMI values depicted no such significance. The proposed system has achieved 93% segmentation accuracy of the exudates region from digital fundus images when ground truth (hand drawn) results are considered as standard. In addition, the traditional F-score, precession and recall values were 88.2, 93.1 and 89.3% respectively. However, these results need to be validated in future clinical trials.