Chapter 7

DIABETIC RETINOPATHY GRADING

A consistent approach to the grading of severity of diabetic retinopathy by an ophthalmologist to treat the patients suffering with diabetic retinopathy is utmost important. This chapter presents a brief overview of grading diabetic retinopathy into different stages of non proliferative DR and also grades diabetic maculopathy. 4-2-1 rule used by the ophthalmologist is implemented to accomplish the task of grading non-proliferative diabetic retinopathy. Various methods developed for extracting pathologies associated with diabetic retinopathy are analysed and, based on the results of these methods the image is classified into one of the stages of non proliferative diabetic retinopathy. The results obtained are verified by an expert for its correctness.

7.1 Grading Diabetic Retinopathy

Diabetic retinopathy is one of the complications of diabetes mellitus that is considered as the major cause of vision loss among people around the world. The most important signs of diabetic retinopathy are dark lesions (i.e. microaneurysms and hemorrhages) and bright lesions (i.e. hard exudates and cotton wool spots). Advances in digital imaging have opened new avenues for assessing retinopathy, which may provide better access to diagnosis and management for this treatable, but often blinding, condition.

Treatments of diabetic retinopathy cases using laser technology are available. Laser, if applied appropriately and in a timely manner, reduces the risk of vision loss. Hence, it is important to be able to grade a person’s retinopathy such that the likelihood of vision loss is understood, and appropriate management that will reduce the risk of vision loss is provided. Particular patterns of retinal features (dark lesions and bright lesions) start appearing as diabetic retinopathy progresses. Recognizing these patterns can be used to grade the retinopathy.

In this chapter, an efficient method to grade the severity of diabetic retinopathy in retinal images is presented. The system of grading presented in this chapter is applied to
diabetes retinal screening algorithms proposed in earlier chapters. Methods using morphological operations are used to detect the pathologies associated with diabetic retinopathy, namely, blood vessels, microaneurysms and hard exudates. SVM classifier is used to grade the retinal image under the categories of Non Proliferative DR (NPDR) namely, normal (no DR), mild NPDR, moderate NPDR and severe NPDR.

7.1.1 Methodology

NPDR is further subdivided based on retinal findings:

- Early NPDR – At least one microaneurysms present on retinal exam.
- Moderate NPDR – Characterized by multiple microaneurysms, dot-and-blot hemorrhages, venous beading, and/or cotton wool spots.
- Severe NPDR – In the most severe stage of NPDR, you will find cotton wool spots, venous beading, and severe intra retinal microvascular abnormalities (IRMA). It is diagnosed using the "4-2-1 rule." A diagnosis is made if the patient has any of the following: diffuse intra retinal hemorrhages and microaneurysms in 4 quadrants, venous beading in ≥2 quadrants or IRMA in ≥1 quadrant.

The grading system of diabetic retinopathy requires following features to be extracted from fundus images.

- Blood vessel network
- Microaneurysms
- Exudates
- Optic disc.

To grade the DR, features are computed from the pre-processed fundus image. Distribution of microaneurysms and exudates on retinal surface are computed by dividing the fundus image into four quadrants to facilitate implementation of 4-2-1 rule of NPDR classification. SVM classifier is used for grading. The following section describes the procedure for grading fundus images.
SVM Classifier: In Support vector machines, the input is mapped by nonlinear function to a high dimensional space, and the optimal hyper plane finds the largest margin. The support vectors are those patterns that determine the margin; an upper bound on expected error rate of the classifier depends linearly upon the expected number of support vectors. For multi class problems, the linear machines create decision boundaries consisting of sections of such hyper planes.
7.1.2 Algorithm

Input: RGB color fundus image.
Output: classified into one of the stages of non-proliferative diabetic retinopathy.
Method:
Step-1: Execute blood vessel detection algorithm for each quadrant.
Step-2: Execute MA detection algorithm for each quadrant.
Step-3: Execute exudates detection algorithm quadrant.
Step-4: Store area returned by each algorithm into a vector.
Step-5: Repeat step-1 to step-4 for training images and testing images.
Step-6: The stored features are fed to SVM classifier for classification to test images into
✔ NO-DR.
✔ Mild-NPDR.
✔ Moderate-NPDR.
✔ Severe-NPDR.

- The feature vector is of size 9.

FV=[area_BV, area_MA_Q1, area_MA_Q2, area_MA_Q3, area_MA_Q4, area_Ex_Q1, area_Ex_Q2, area_Ex_Q3, area_Ex_Q4]

7.1.3 Experimental Results

The proposed method has been evaluated using 337 fundus images collected from the Karnataka Institute of Diabetology, Bangalore. All the three features of Diabetic retinopathy have been detected successfully. In the normal images the blood vessels occupy the larger area and microaneurysms and exudates are absent. In case of mild NPDR and moderate NPDR, the microaneurysms & exudates showed their presence and in severe NPDR their prominence is more. An average accuracy of 100%, 93.33%, 100% and 86.67% is obtained for normal, mild NPDR, moderate NPDR, and severe NPDR, respectively. Sensitivity of 96.08% and specificity of 97.92% is observed. The recognition results in case of severe NPDR is low compared to other stages, since many of the fundus images with severe NPDR were misclassified as moderate NPDR. The performance has been evaluated by the experts.
7.1.4 Summary

An automated method for detecting different stages of Non Proliferative Diabetic retinopathy stages is implemented using pathologies associated with DR namely, blood vessels, exudates and microaneurysms. The proposed method is efficient in terms of number of features used and recognition accuracy as against the method proposed by Acharya et al [44]. The classification of stages of NPDR is based upon the presence of exudates and microaneurysms and their distribution in four quadrants of the retinal images. The results are demonstrated for a large dataset of fundus images that includes local dataset and DRIVE dataset. The system is able to classify the NPDR stages into normal, mild NPDR, moderate NPDR and severe NPDR with an average accuracy of 95%, an average sensitivity of 96.08% and an average specificity of 97.92%.

7.2 Grading Diabetic Maculopathy

Diabetic Maculopathy is one of the leading causes for blindness in the world. In grading diabetic retinopathy the features such as exudates and microaneurysms are not only extracted but also study their distribution in the retinal area. This study is also needed in grading Diabetic Maculopathy. In DR grading a quadrant wise retinal area is considered where as in DM grading the retina is divided using circles. The center of the circle is foveola. Five circles are drawn marking Optic Disc, foveola, fovea, parafovea and perifovea regions. The grading of DM as non-CSME and CSME is done based on the number of exudate pixels present in each of the four regions excluding optic disc. Hence optic disc and fovea center identification

<table>
<thead>
<tr>
<th>Stages</th>
<th>No. of data sets used for training</th>
<th>No. of data sets used for testing</th>
<th>% of correct classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>22</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>Mild NPDR</td>
<td>60</td>
<td>40</td>
<td>93.33</td>
</tr>
<tr>
<td>Moderate NPDR</td>
<td>60</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>Severe NPDR</td>
<td>60</td>
<td>40</td>
<td>86.67</td>
</tr>
</tbody>
</table>

Table 3: Diabetic retinopathy results using SVM classifier
are the important steps in grading DM. The association of same pathologies for grading DR and DM encouraged us to implement the proposed method.

### 7.2.1 Methodology

The grading system of diabetic maculopathy is divided into three sub tasks. These sub tasks are to identify the optic disc center, locate fovea, and finally extract exudates. Features are computed from the pre processed fundus image in reference with ophthalmologist. Distribution of exudates on retinal surface is computed by dividing the fundus image into four circular regions foveola (R1), fovea (R2), parafovea (R3) and perifovea (R4) to facilitate diabetic maculopathy classification. The following section describes feature extraction methods.

Optic disc is located using method-2 (Hough transform for fitting circle). Center of the optic disc is selected and it is used as reference to locate the fovea. The fovea center is present at a distance from optic disc approximately 2.5 times the diameter of optic disc and occupies 11X11 area. This prior knowledge and a method composed of morphological operations, extended minima transform and centroid computation is used to locate the center of fovea. The exudates extraction is achieved using method-3 (3-sigma control limits).

![Figure 41: Block Diagram for grading Diabetic Maculopathy](image-url)
### 7.2.2 Algorithm

**Input:** RGB color fundus image.

**Output:** Image graded as CSME or non-CSME.

**Method:**

1. Locate optic disc using Hough transform method.
2. Locate fovea center.
3. Extract exudates using 3-sigma control limits.
4. Mark the regions for grading diabetic maculopathy.
5. Feed the nearest neighbor classifier for classification.

- The feature vector is of size 4.

\[
FV = [\text{area of exudates in R1}, \text{area of exudates in R2}, \text{area of exudates in R3}, \text{area of exudates in R4}]
\]

### 7.2.3 Experimental Results

Grading diabetic maculopathy is a two class classification problem. Nearest Neighbour (NN) classifier is used for the classification. 40 images collected from Karnataka Institute of Diabetology, Bangalore are used to test the algorithm. The five regions on the retina i.e., optic disc, foveola, fovea, parafovea and perifovea are marked [figure 42] and the area of exudates in each of these regions is calculated and the so obtained values form the feature vector for classification.

![Figure 42: Results of marking four regions along with exudates](image-url)
The feature vector (table 4) of size four consisting of exudates in foveola (R1), fovea (R2), parafovea (R3) and perifovea (R4) are fed to the nearest neighbor classifier that has yielded 100% results.

Table 4: Sample Output of grading diabetic maculopathy algorithm

<table>
<thead>
<tr>
<th>Image</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>975</td>
<td>1 (Non CSME)</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>38</td>
<td>202</td>
<td>1 (Non CSME)</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>227</td>
<td>1 (Non CSME)</td>
</tr>
<tr>
<td></td>
<td>266</td>
<td>310</td>
<td>0</td>
<td>0</td>
<td>2 (CSME)</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>170</td>
<td>29</td>
<td>590</td>
<td>2 (CSME)</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>353</td>
<td>1533</td>
<td>570</td>
<td>2 (CSME)</td>
</tr>
</tbody>
</table>
7.2.4 Summary
The objective of grading diabetic maculopathy algorithm is to extend the work of grading diabetic retinopathy to grading exudative diabetic maculopathy using the methods proposed for extracting exudates and optic disc in chapter 4 and chapter 5. Algorithm has been presented for detection of fovea center. The method has been tested on the local database of fundus images. The results obtained are encouraging. The nearest neighbor classifier has yielded a 100% results with the feature extracted for grading maculopathy.