Feature Extraction for Diagnosis of Diabetic Retinopathy

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What is Diabetic Retinopathy?

Diabetes occurs when the pancreas does not secrete enough insulin, or the body is unable to process insulin properly.

**Complication of Diabetes**
- Effects kidneys, eyes, nerves, and heart
- Abnormal rises in glucose levels damage blood vessels

**Diabetic Retinopathy**
Over time, the damage to blood vessels in the eye causes loss of vision, and in some cases complete blindness. This complication is called *Diabetic Retinopathy*. 
What is Diabetic Retinopathy? (cont’d)

DR Gives Insight into Overall Patient Health
- Fundus Imagery provides a look at the patient’s blood vessels
- Non-invasive
- At least 40% of people with Diabetes show signs of DR.

Early Detection of DR Crucial to Treatment
- The most effective treatment for DR can be administered only in the first stages of the disease.
- Early detection through regular screening is of paramount importance.
Diabetic Retinopathy Ranking System

Rank 0 (a):
No symptoms of Diabetic Retinopathy present.

Rank 1 (b): Mild Non-Proliferate Diabetic Retinopathy
- At least one microaneurysm.
- With or without the presence of:
  - Retinal hemorrhages.
  - Hard exudates.
  - Cotton wool spots.
  - Venous loops.

Rank 2 (c): Moderate Non-Proliferate Diabetic Retinopathy
- Numerous microaneurysms and retinal hemorrhages are present.
- A limited amount and cotton wool spots of venous beading can also be seen.

Rank 3 (d): Severe Non-Proliferate Diabetic Retinopathy
SNPDR is classified by any one of the following:
- Numerous hemorrhages and microaneurysms in 4 quadrants of the retina
- Venous beading in 2 or more quadrants
- Intraretinal microvascular abnormalities in at least 1 quadrant

Rank 4 (e): Proliferate Diabetic Retinopathy
Leaked blood contaminates the vitreous gel
## Main Technical Difficulties

### Noisy Images

![Noisy Images](image1.png)

### Different Camera Types

![Different Camera Types](image2.png)

### Large Images, Involved Processing

To scale: 3888x2592 (left) vs. 256x256 (right)

![Large Images](image3.png)
Kaggle

- The world’s largest community of data scientists
- Competitions hosted by organizations who don’t have access to advanced machine learning techniques.
- Data scientists from all fields of research join forces to solve relevant problems
- Offering $100K to the creator of the most effective DR ranking algorithm
General Methodology

Strategy for DR Classification

- Pre-process the image set to make more uniform
- Use algorithms to detect and evaluate features
- Feed features into classification algorithms
  - Support Vector Machines (SVM)
  - Neural Networks
  - C-Means Classifiers
# Feature Detection Algorithms and Their Success [1]

<table>
<thead>
<tr>
<th>Authors</th>
<th>No of classes</th>
<th>Method</th>
<th>Accuracy of classification</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wang et al. 2000</td>
<td>2</td>
<td>Minimum distance discriminant classifier</td>
<td>70%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinthanayothin et al. 2003</td>
<td>2</td>
<td>Most operator</td>
<td>Not reported</td>
<td>80%</td>
<td>71%</td>
</tr>
<tr>
<td>Usher et al. 2003</td>
<td>2</td>
<td>Lesions</td>
<td>Not reported</td>
<td>95%</td>
<td>53%</td>
</tr>
<tr>
<td>Singalavania et al. 2005</td>
<td>2</td>
<td>Blood vessels, exudates, haemorrhages, microaneurysms</td>
<td>Not reported</td>
<td>75%</td>
<td>83%</td>
</tr>
<tr>
<td>Lee et al. 2005</td>
<td>3</td>
<td>Hemorrhages, microaneurysms, hard exudates, cotton wool spots</td>
<td>Max: 88%</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Neubauer et al. 2005</td>
<td>2</td>
<td>Retinal thickness analyzer</td>
<td>Not reported</td>
<td>93%</td>
<td>100%</td>
</tr>
<tr>
<td>Kahai et al. 2006</td>
<td>2</td>
<td>Decision support system (DSS)</td>
<td>Not reported</td>
<td>100%</td>
<td>63%</td>
</tr>
<tr>
<td>Philip et al. 2007</td>
<td>2</td>
<td>Exudates</td>
<td>Not reported</td>
<td>91%</td>
<td>67%</td>
</tr>
<tr>
<td>Estabridis and Figueiredo</td>
<td>2</td>
<td>Fovea, blood vessel network, optic disk, bright and dark lesions</td>
<td>90%</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Li et al. 2008</td>
<td>2</td>
<td>Bright lesions, retinal vessel patterns</td>
<td>Not reported</td>
<td>81%</td>
<td>Not reported</td>
</tr>
<tr>
<td>Abramoff et al. 2008</td>
<td>3</td>
<td>Optic disc, retinal vessels, hemorrhages, microaneurysms, vascular, abnormalities, exudates, cotton wool spots, druseen</td>
<td>Not reported</td>
<td>84%</td>
<td>64%</td>
</tr>
<tr>
<td>Wong et al. 2008</td>
<td>4</td>
<td>Area of blood vessel</td>
<td>84%</td>
<td>92%</td>
<td>100%</td>
</tr>
<tr>
<td>Nayak et al. 2008</td>
<td>3</td>
<td>Blood vessels, exudates and texture</td>
<td>94%</td>
<td>90%</td>
<td>100%</td>
</tr>
<tr>
<td>Acharya et al. 2008</td>
<td>5</td>
<td>Higher order spectra</td>
<td>82%</td>
<td>83%</td>
<td>89%</td>
</tr>
<tr>
<td>Acharya et al. 2009</td>
<td>5</td>
<td>Blood vessel, exudates, microaneurysms, haemorrhages</td>
<td>86%</td>
<td>82%</td>
<td>86%</td>
</tr>
<tr>
<td>Vujosevic et al. 2009</td>
<td>2</td>
<td>Single lesions</td>
<td>Not reported</td>
<td>82%</td>
<td>92%</td>
</tr>
</tbody>
</table>
Pseudocode for Image Pre-Processing

**Green Channel Extraction**
Research has shown that the green channel of an RGB digital fundus image yields the most precise results. [1]
- Green_Channel = Original_Image(:, :, 2)

**Normalizing and Inverting the Image**
Normalize the green channel, invert the image.
- Normalized_Image = mat2gray(Green_Channel)
- Inverted_Image = imadjust(Normalized_Image,[0;1],[1;0])

**Detecting Edge of the Frame**
The edge of the frame is frequently subtracted from the results of other feature detection algorithms for use of imfill().
- SD = strel('disk',8);
- Eroded = imerode(Inverted_Image,SD);
- Dilated =imdilate(Inverted_Image,SD);
- Diff = Dilated-Eroded
- Edge = im2bw(Diff,.099)
Results of Pre-Processing

**Figure 1:** Results of image preprocessing after:

a) Grayscale conversion  

b) Intensity inversion  

c) Edge detection
Pseudocode for Blood Vessel Detection

**Adaptive Histogram Equalization**
Smoothes image and increases contrast
- \( \text{AHE} = \text{adapthisteq}(\text{Original Image}) \)

**Morphological Opening**
Opening with a disk-shaped element will reveal all the circularly shaped parts of the image:
- \( \text{SD} = \text{strel('disk',8)} \rightarrow \text{Opened Image} = \text{imopen(AHE,SD)} \)

**Subtract Opened Image from High Contrast Image**
Subtracting these circular parts of the image from the original yields blood vessels only:
- \( \text{BV Img} = \text{AHE} - \text{Opened Image} \)

**Binarize Image**
- \( \text{BV BW} = \text{im2bw(Blood Vessel Img,.099)} \)

**Median Filter Image**
- \( \text{BV Med} = \text{medfilt2(BV BW)} \)

**Remove Boundary and Fill Holes**
- \( \text{BV Sub} = \text{BV Med} - D \)
- \( \text{BV Final} = \text{imfill(BV Sub,'holes')} \)
Results of Blood Vessel Detection Algorithm (Healthy Eye)

Figure 2: Healthy eye blood vessel detection after:
- a) Adaptive histogram equalization
- b) Image opening
- c) Image subtraction
- d) Binary thresholding
- e) Edge subtraction
- f) Image fill and inversion
Results of Blood Vessel Detection Algorithm (Mild NPDR)

Figure 3: Mild NPDR blood vessel detection after:
- a) Adaptive histogram equalization
- b) Image opening
- c) Image subtraction
- d) Binary thresholding
- e) Edge subtraction
- f) Image fill and inversion
# Pseudocode for Exudate Detection

## Octagon/Disk Morphological Openings

- SD = strel('disk',8) → Disk_Opened = imopen(Original_Image, SD)
- SO = strel('octagon',9) → Octagon_Opened = imopen(Disk_Opened,SO)

## Closing Using Octagon Shape

- SOB = strel('octagon',30) → Octagon_Closed = imclose(Octagon_Opened,SOB)

## Binarized Image

- Bin_Img = im2bw(Octagon_Closed,.3)

## Open Using Disk Shape

- Final_Img = imopen(Bin_Img,SD)
Results of Exudate Detection Algorithm (PDR)

Figure 4: Proliferate DR exudate detection after:
- a) Disk opening
- b) Small octagon opening
- c) Large octagon opening
- d) Final black & white threshold
Figure 5: Healthy eye exudate detection after:
  a) Disk opening
  b) Small octagon opening
  c) Large octagon opening
  d) Final black & white threshold
The process for hemorrhage detection is essentially the same as that for exudate detection, but using a smaller threshold levels for binary conversion.
Results of Hemorrhage and Micro-aneurysm Detection Algorithm (PDR)

Figure 6: Proliferate DR hemorrhage/micro-aneurysm detection after:
- a) Disk opening
- b) Small octagon opening
- c) Large octagon opening
- d) Final black & white threshold
Results of Hemorrhage and Micro-aneurysm Detection Algorithm (Healthy Eye)

Figure 7: Healthy eye hemorrhage/micro-aneurysm detection after:
- a) Disk opening
- b) Small octagon opening
- c) Large octagon opening
- d) Final black & white threshold
Most classification begins with finding distinct features to feed your algorithms.

This amounts to a large amount of legwork in image pre-processing.

Morphological openings/closings are your friends:
- Noise removal
- Shape detection
Future Work

- Find more robust algorithms for hemorrhage and micro-aneurysm detection
- Apply feature extraction to each image
- Feed feature vectors into different classification algorithms
References


Any Questions?