Feature Extraction for Diagnosis of Diabetic Retinopathy

Teal Hobson-Lowther

Colorado School of Mines

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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 Retinopaty 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.

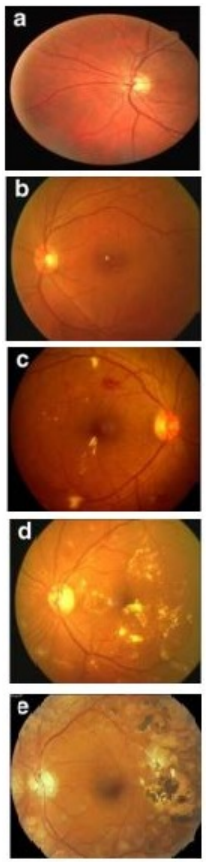
Rank 3 (d): Severe Non-Proliferate Diabetic Retinopathy

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

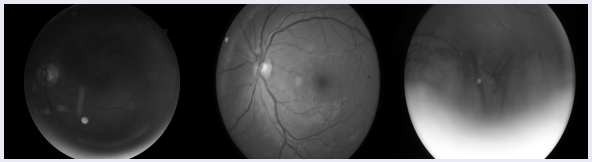
Leaked blood contaminates the vitreous gel



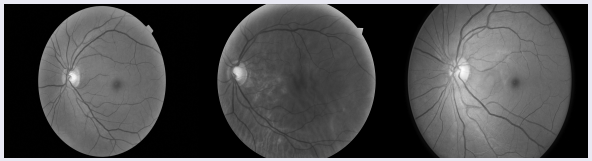
[1]

Main Technical Difficulties

Noisy Images



Different Camera Types



Large Images, Involved Processing

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

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]

Authors	No of classes	Method	Accuracy of classification	Sensitivity	Specificity
Wang et al. 2000 [73]	2	Minimum distance discriminant classifier	70%		
Sinthanayothin et al. 2003 [66]	2	Moat operator	Not reported	80%	71%
Usher et al. 2003 [82]	2	Lesions	Not reported	95%	53%
Singalavanija et al. 2005 [81]	2	Blood vessels, exudates, haemorrhages, microaneurysms	Not reported	75%	83%
Lee et al. 2005 [43]	3	Hemorrhages, microaneurysms, hard exudates, cotton wool spots	Max: 88%	Not reported	Not reported
Neubauer et al. 2005 [50]	2	Retinal thickness analyzer	Not reported	93%	100%
Kahai et al. 2006 [36]	2	Decision support system (DSS)	Not reported	100%	63%
Philip et al. 2007 [57]	2	Exudates	Not reported	91%	67%
Estabridis and Figueiredo 2007 [20]	2	Fovea, blood vessel network, optic disk, bright and dark lesions	90%	Not reported	Not reported
Li et al. 2008 [46]	2	Bright lesions, retinal vessel patterns	Not reported	81%	Not reported
Abràmoff et al. 2008 [2]	3	Optic disc, retinal vessels, hemorrhages, microaneurysms, vascular, abnormalities, exudates, cotton wool spots, drusen	Not reported	84%	64%
Wong et al. 2008 [75]	4	Area of blood vessel	84%	92%	100%
Nayak et al. 2008 [48]	3	Blood vessels, exudates and texture	94%	90%	100%
Acharya et al. 2008 [3]	5	Higher order spectra	82%	83%	89%
Acharya et al. 2009 [5]	5	Blood vessel, exudates, microaneurysms, haemorrhages	86%	82%	86%
Vujosevic et al. 2009 [71]	2	Single lesions	Not reported	82%	92%

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

Smooths image and increases contrast

- AHE = adapthisteq(Original_Image)

Morphological Opening

Opening with a disk-shaped element will reveal all the circularly shaped parts of the image:

- SD = strel('disk',8) $\rightarrow$
  Opened_Image = imopen(AHE,SD)

Subtract Opened Image from High Contrast Image

Subtracting these circular parts of the image from the original yields blood vessels only:

- BV_Img = AHE - Opened_Image

Binarize Image

- BV_BW = im2bw(Blood_Vessel_Img,.099)

Median Filter Image

- BV_Med = medfilt2(BV_BW)

Remove Boundary and Fill Holes

- BV_Sub = BV_Med - D
- BV_Final = imfill(BV_Sub,'holes')

Results of Blood Vessel Detection Algorithm (Healthy Eye)

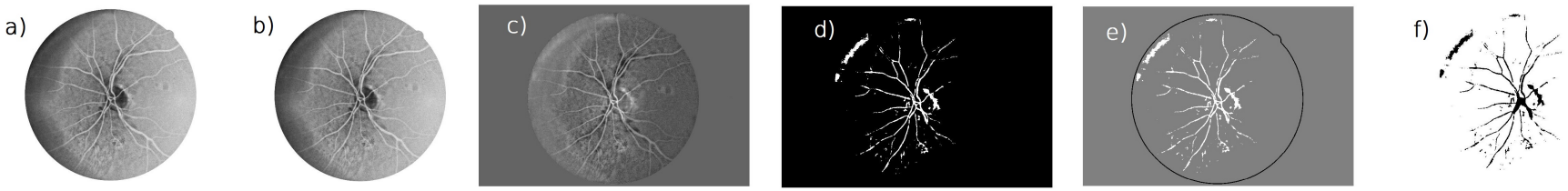


Figure 2: Healthy eye blood vessel detection after:
a) Adaptive histogram equalization
b) Image opening
c) Image subtraction
d) Binary thresholding
e) Edge subtraction
f) Image fill and inversion

Results of Blood Vessel Detection Algorithm (Mild NPDR)

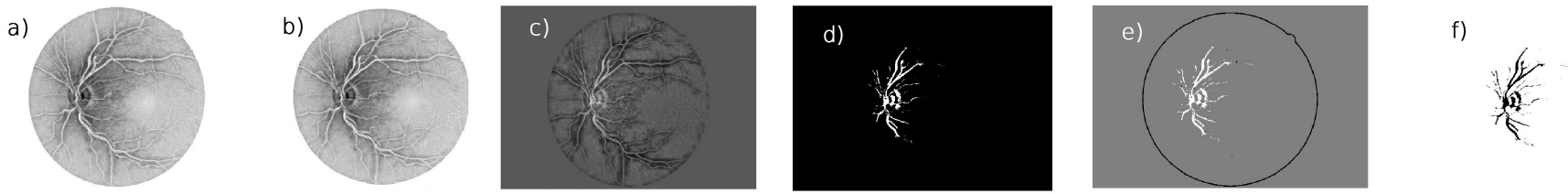


Figure 3: Mild NPDR blood vessel detection after:
a) Adaptive histogram equalization
b) Image opening
c) Image subtraction
d) Binary thresholding
e) Edge subtraction
f) Image fill and inversion

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)

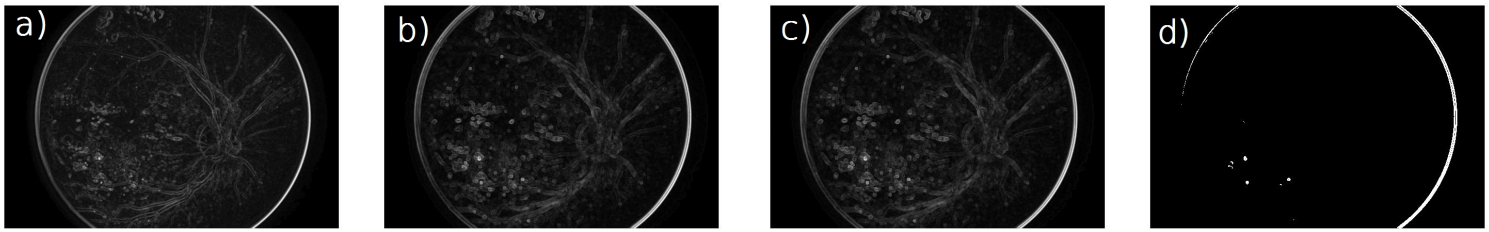


Figure 4: Proliferate DR exudate detection after:
a) Disk opening
b) Small octagon opening
c) Large octagon opening
d) Final black & white threshold

Results of Exudate Detection Algorithm (Healthy Eye)

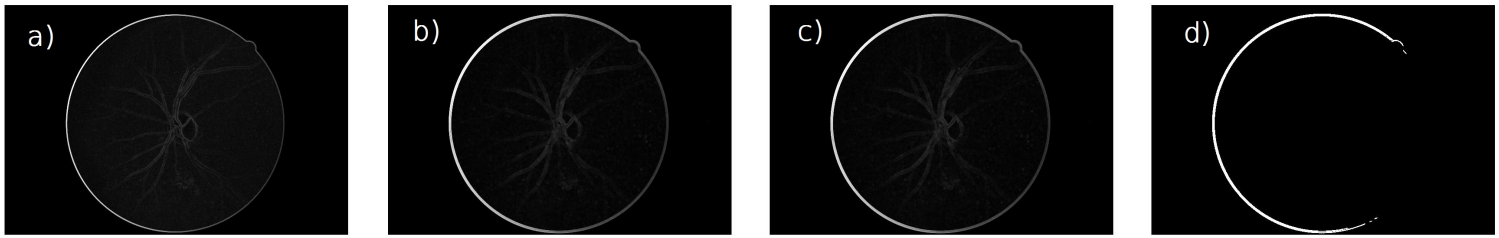


Figure 5: Healthy eye exudate detection after:
a) Disk opening
b) Small octagon opening
c) Large octagon opening
d) Final black & white threshold

Hemorrhage and Micro-aneurysm Detection Algorithm

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)

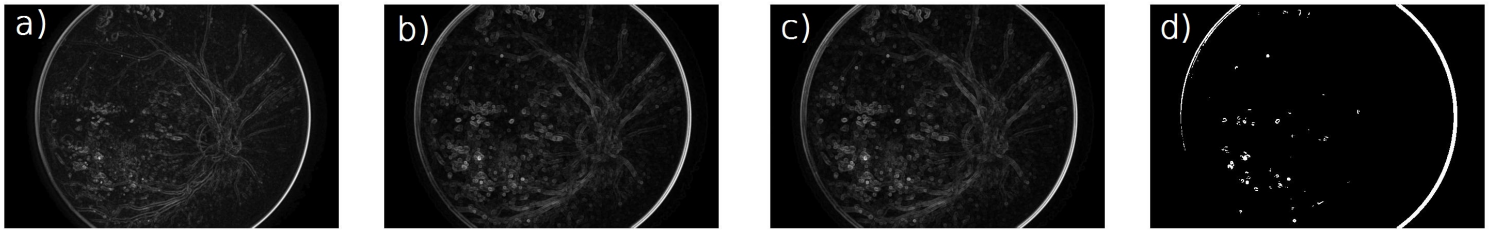


Figure 6: Proliferate DR hemorrhage/micro-aneurysm detection after:
a) Disk opening
b) Small octagon opening
c) Large octagon opening
d) Final black & white threshold

Results of Hemorrhage and Micro-aneurysm Detection Algorithm (Healthy Eye)

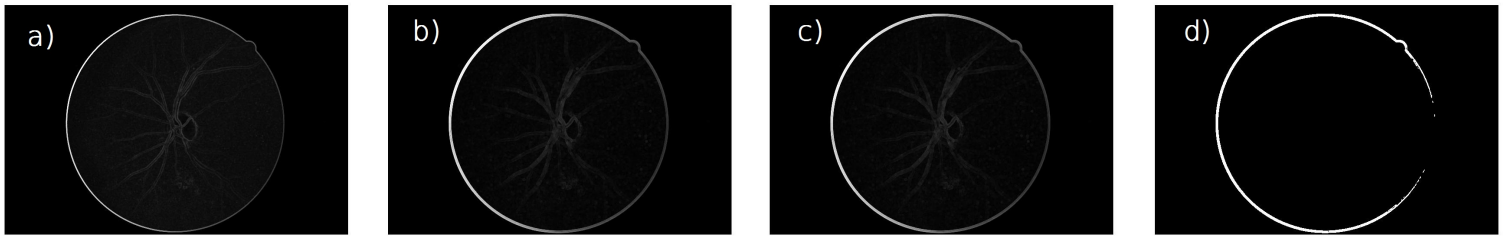


Figure 7: Healthy eye hemorrhage/micro-aneurysm detection after:
a) Disk opening
b) Small octagon opening
c) Large octagon opening
d) Final black & white threshold

Take Away

- 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

[1] Faust, Oliver, Rajendra Acharya U., E. Y. K. Ng, Kwan-Hoong Ng, and Jasjit S. Suri. "Algorithms for the Automated Detection of Diabetic Retinopathy Using Digital Fundus Images: A Review." Journal of Medical Systems 36.1 (2012): 145-57. Web.

[2] Lupascu, Carmen A., Domenico Tegolo, and Emanuele Trucco. "FABC: Retinal Vessel Segmentation Using AdaBoost." *IEEE Transactions on Information Technology in Biomedicine* 14.5 (2010): 1267-274. Print.

[3] Staal, J., M.d. Abramoff, M. Niemeijer, M.a. Viergever, and B. Van Ginneken. "Ridge-Based Vessel Segmentation in Color Images of the Retina." *IEEE Transactions on Medical Imaging* 23.4 (2004): 501-09. Web.

Ponderers Anonymous

Any Questions?