Quantification of Retinal Tissue Damage

Semester Long Project : 2016-17

Mentored by: **Dr. Nirmal Yadav**

Raghav Singh - 11522

Sanjeev Dubey - 11528

Utkarsh Mittal - 11536

Retinal image examination techniques

OCT

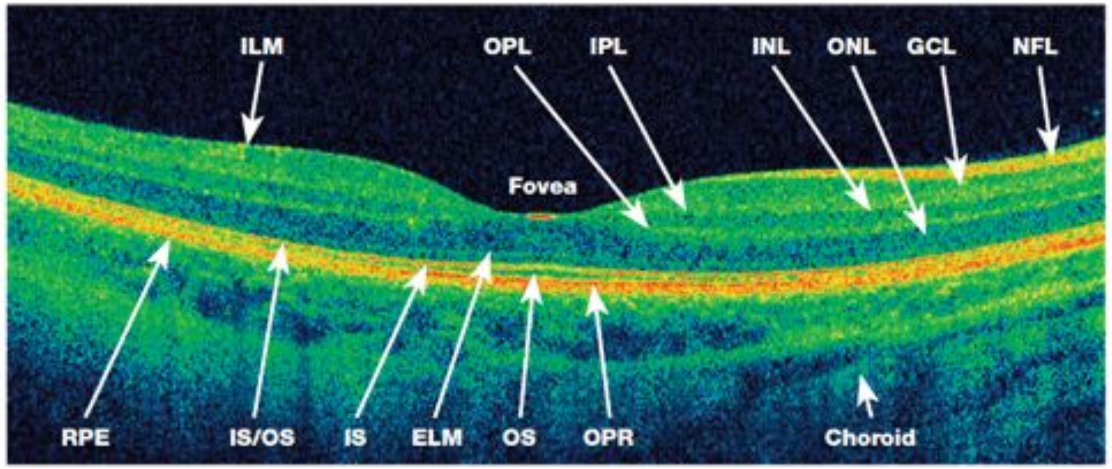
- 3-D profile consisting of different layers of retina

Fundus

- capturing a photograph of the back of the eye using specialized fundus cameras

Optical Coherence Tomography

An HD-OCT scan of a healthy eye



NFL: Nerve fiber layer
ILM: Inner limiting membrane
GCL: Ganglion cell layer
IPL: Inner plexiform layer
INL: Inner nuclear layer

OPL: Outer plexiform layer
ONL: Outer nuclear layer
ELM: External limiting membrane
IS: Photoreceptor inner segment
OS: Photoreceptor outer segment

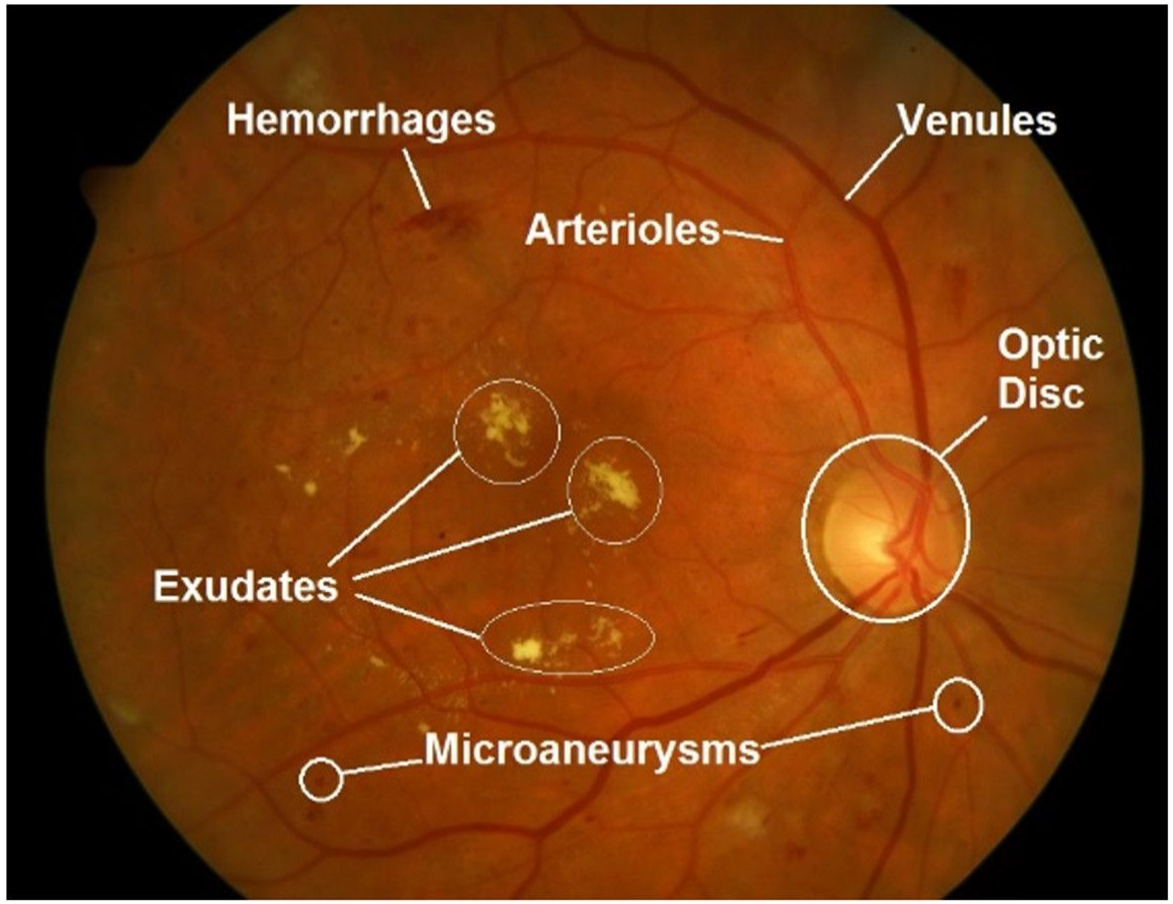
IS/OS: Interface between IS and OS
RPE: Retinal pigment epithelium
OPR: Outer photoreceptor/ RPE complex

https://www.healthpartners.com.au/optical/products/eye-examinations/optical-coherence-tomography

Fundus photography

The abnormalities depicting the damage in the fundus images are:

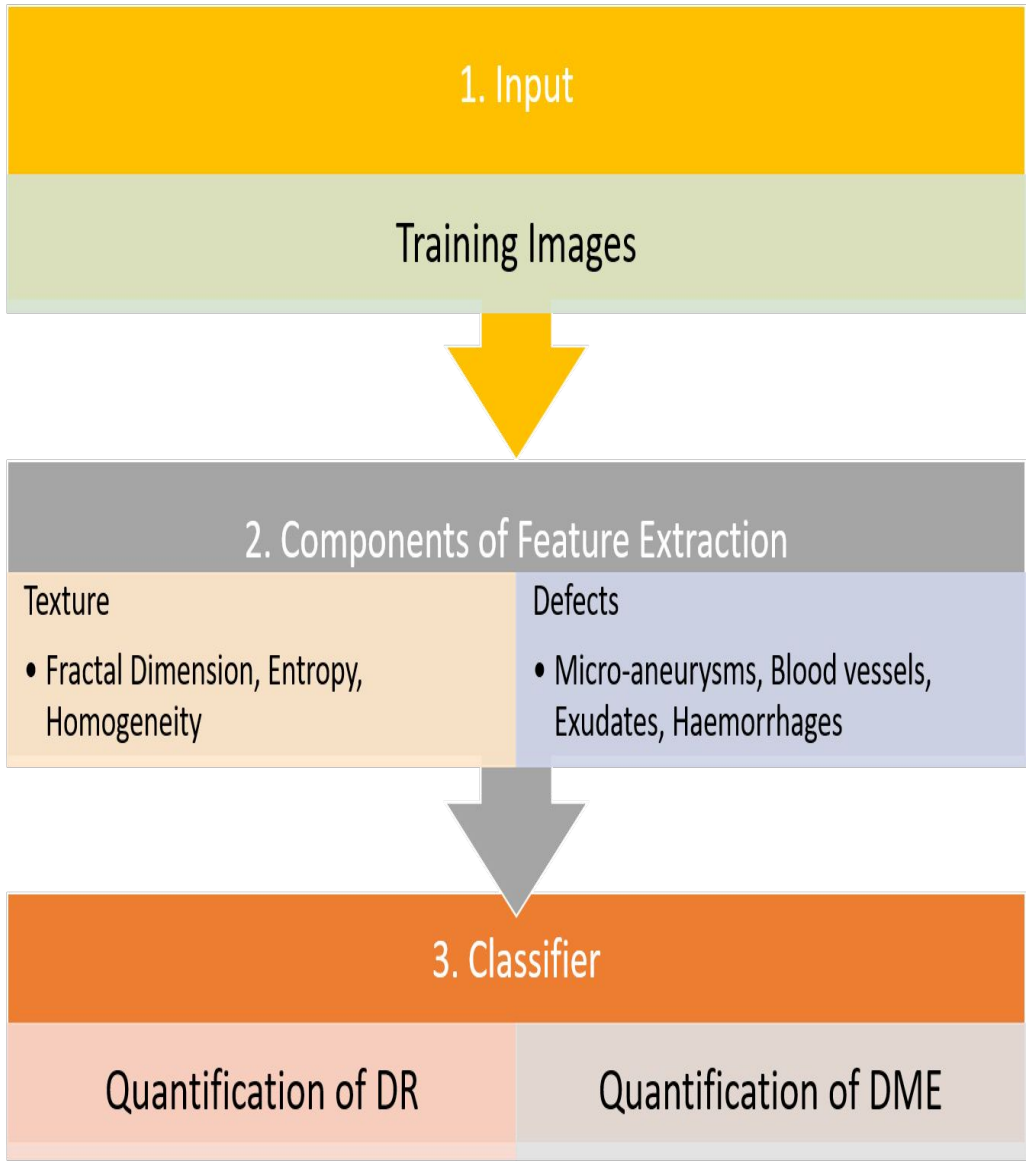
1. **Microaneurysm**- microscopic blood-filled bulges in the artery walls.
2. **Exudates**- bright, small spots, consisting of lipids, which can have irregular shape.
3. **Hemorrhages**- chunks of blood vessels, appearing as red blobs, lying on the retina because of blood vessel rupture.
4. **Blood vessels**- formation of new blood vessels which are weak and disoriented which sometimes causes them to leak inside vitreous.



A labelled fundus image depicting features of retina.

Methodology

- We try with different set of retinal defects to address a particular disease.



Targeted Retinal defects / features

Texture Analysis

1. Fractal Dimension
2. Entropy
3. Homogeneity

Defects

1. Blood Vessels
2. Haemorrhages
3. Exudates
4. Microaneurysms

Entropy and Homogeneity

1. Gray level co-occurrence Matrix (GLCM)
2. $$H = \sum_i \sum_j \frac{1}{1+(i-j)^2} p_d(i,j)$$

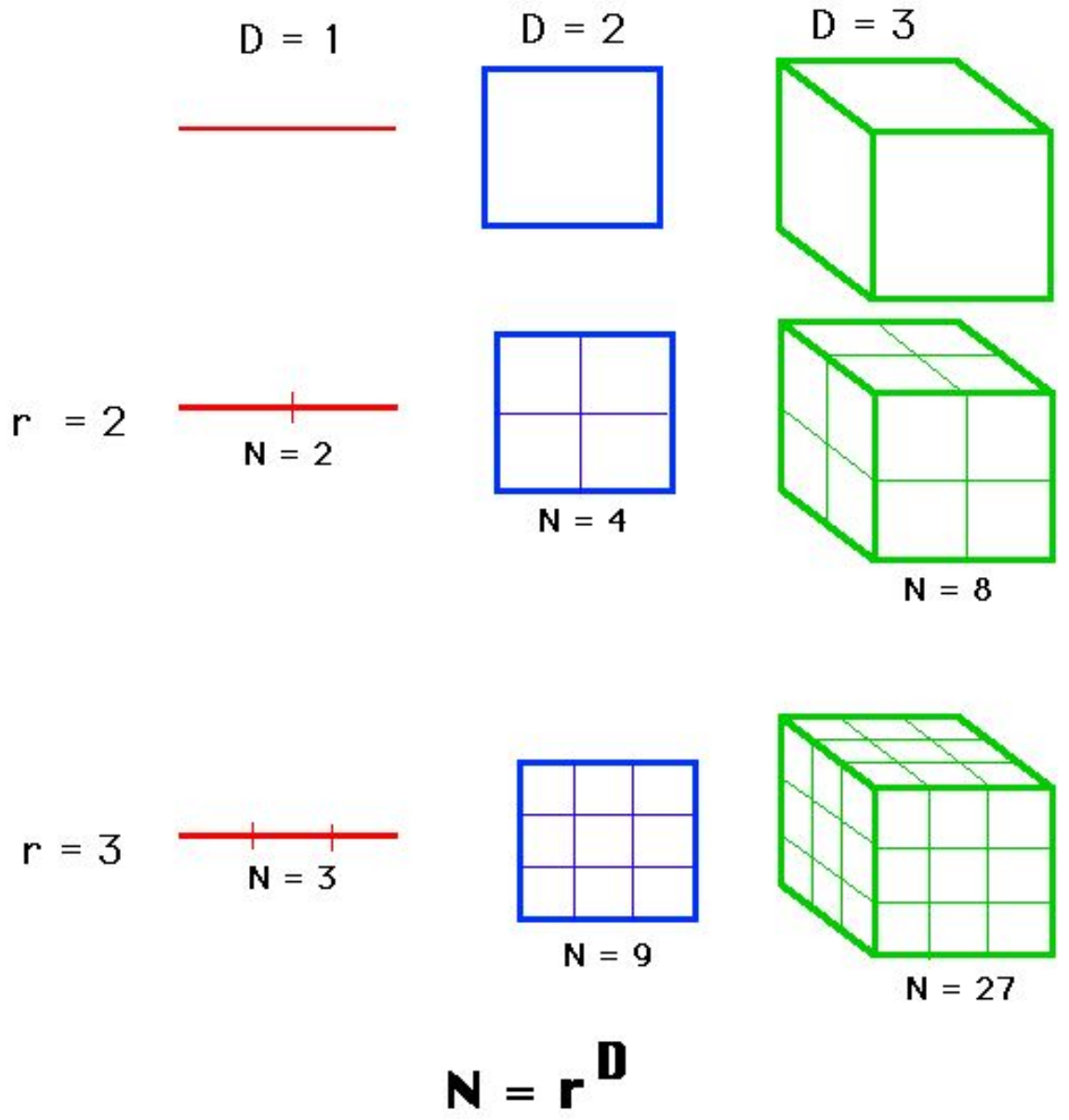
Where pd is the probability of having a pair of pixel values (i,j) occurring in each image and (i,j) denotes a possible pair of the horizontally adjacent pixels i and j.

3. $$E = -\sum_i \sum_j (p * log_2 p)$$

where p is histogram values of gray scale image at different (i, j).

Fractal Dimension

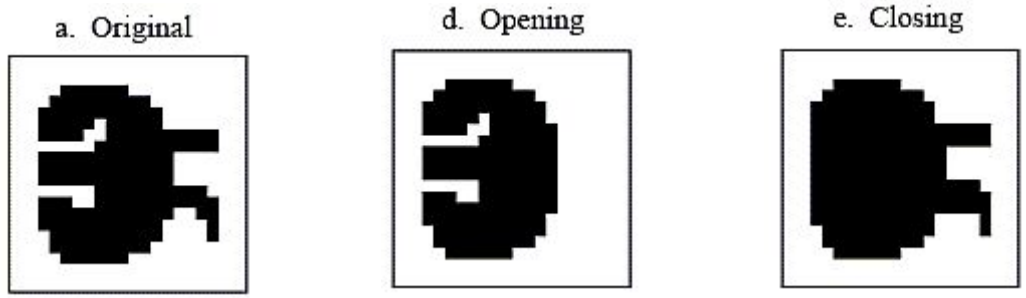
- For fundus images we have extracted Hausdorff fractal dimension.
- Fractal dimension of an image is a measure of roughness.



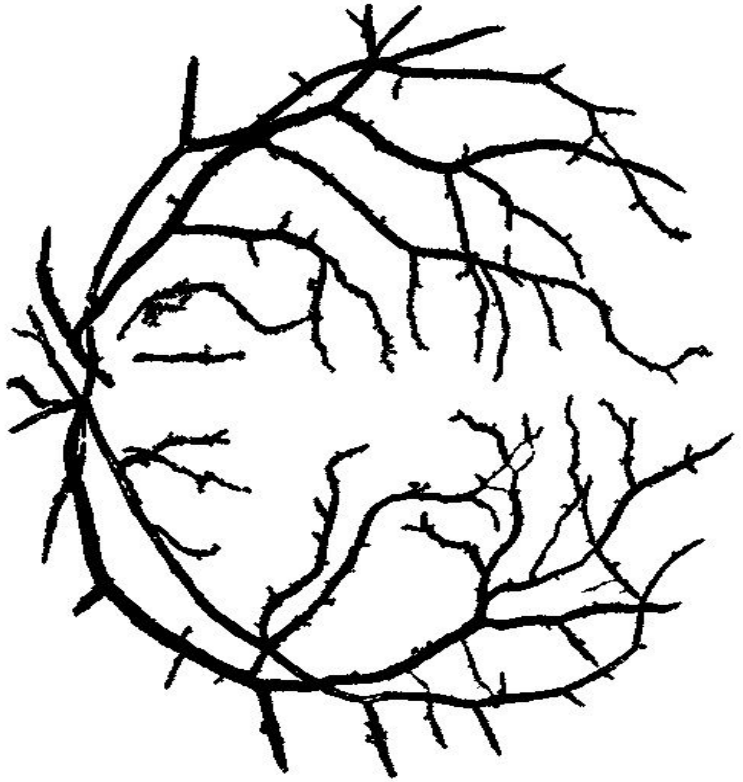
Fractal Dimension for n = 1,2 and 3

Image Processing techniques

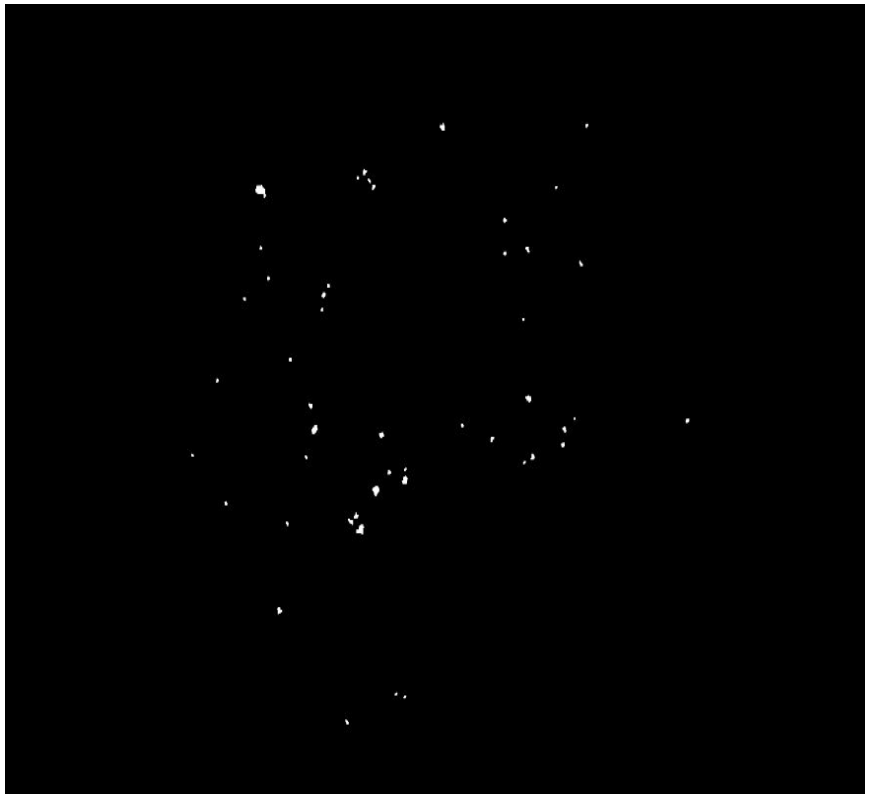
- Morphological processing
- CLAHE
- Canny edge detection
- Thresholding
- Contours/blobs



Blood Vessel Segmentation



Microaneurysm detection

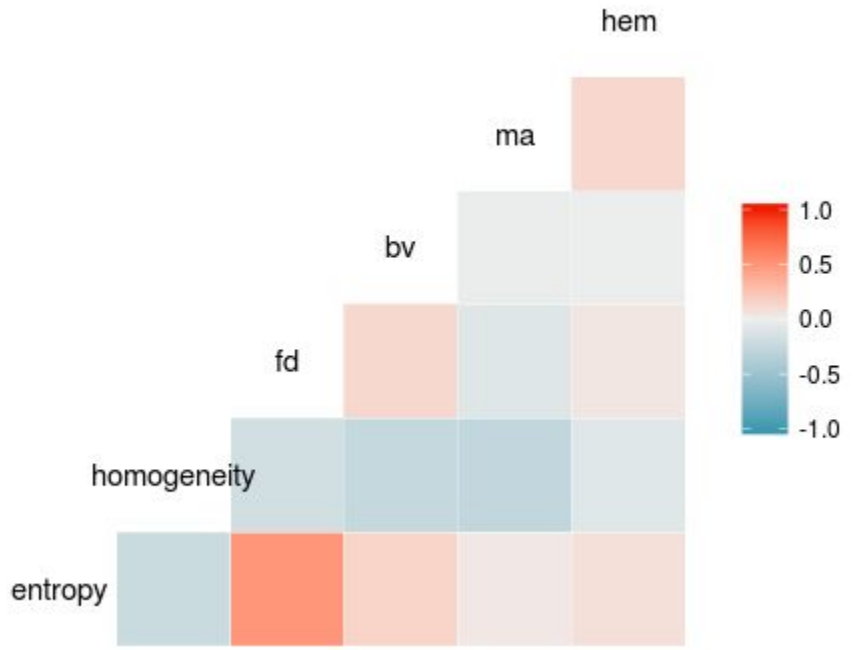


Haemorrhages detection

Exudates detection

Correlation matrix

- Before training a classifier we must analyze the dependence between different features.
- Correlation matrix shows us a positive correlation between fractal dimensions and entropy.
- Dropping either of them should not change much in accuracy



- **For Diabetic Retinopathy (Binary Classification) :**

Machine Learning Model	Accuracy
Support Vector Machine	0.6634867
Random Forest	0.6657898
k-Nearest Neighbor	0.5176392
Adaboost	0.6621927
Artificial NN	0.6500546
Naive - Bayes	0.6482322
Linear Discriminant Analysis	0.6427890

- **For Macular Edema (Binary Classification) :**

Machine Learning Model	Accuracy
Support Vector Machine	0.7249993
Random Forest	0.7306538
k-Nearest Neighbor	0.5652262
Adaboost	0.6677390
Artificial NN	0.7218929
Naive - Bayes	0.7220698
Linear Discriminant Analysis	0.7312409

- **For Macular Edema (Multiclass Classification) :**

  Accuracy under this case was **0.81** by **random forests** classifier with all 6 features included.

  Now, under a special case as there is a correlation between FD and entropy. Entropy was removed and accuracy on the same was found to be **0.81.**

Results and Discussion :

- Through morphological operations blood vessel segmentation has been achieved. The results are found to be very consistent and better than most of previous works.
- Results of extraction of exudates and microaneurysms have shown great success.
- Haemorrhages could not be segmented very precisely.

- Microaneurysms are the most crucial and distinguishing features in DR and ME detection.
- Fractal Dimensions and Entropy have positive correlation. So one of them should be left out.
- A multiclass classifier for Macular Edema with 1200 data points gives with an accuracy of 81% has been designed.

References

- Zhou, H. W., and H. Xie. "Direct estimation of the fractal dimensions of a fracture surface of rock." *Surface Review and Letters* 10.05 (2003): 751-762
- DeBuc, Delia Cabrera, and Gabor Mark Somfai. "Early detection of retinal thickness changes in diabetes using optical coherence tomography." *Medical Science Monitor* 16.3 (2010): MT15-MT21.
- Decencière, Etienne, Xiwei Zhang, Guy Cazuguel, Bruno Lay, Béatrice Cochener, Caroline Trone, Philippe Gain, Richard Ordonez, Pascale Massin, Ali Erginay, Béatrice Charton, & Jean-Claude Klein. "FEEDBACK ON A PUBLICLY DISTRIBUTED IMAGE DATABASE: THE MESSIDOR DATABASE." Image Analysis & Stereology [Online], 33.3 (2014): 231-234. Web. 1 May. 2017

Individual Work Done

- Sanjeev- Literature review, ML courses, Image processing courses, feature extraction (blood vessel and haemorrhages), ML analysis

- Raghav- Literature review, ML courses, Image processing courses, feature extraction (microaneurysm), ML analysis, OCT and fundus, made medical background for project

- Utkarsh- Literature review, ML courses, Image processing courses, feature extraction (exudates), ML analysis, Graph visualisations.

Thank You