Diabetic Retinopathy Recognition & Classification

Class project for Medical Image Analysis
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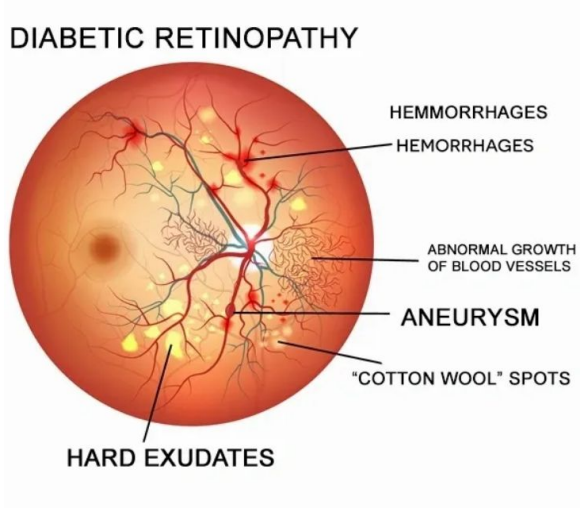
Problem - Background

- A complication of diabetes that affects the eyes
- Diabetes: Type I (juvenile onset) and Type II (adult onset)
- Genetic component involved
- Begin without any warning symptoms
- Early diagnosis and treatment ⟶ risk of blindness reduced by 90%
- Early stages ⟶ no treatment needed
- As disease advances ⟶ laser surgery and intraocular injection
- Diabetic retinopathy is major cause of blindness in India ⟶

  30% of DR cases in the world



Recommended Eye Examination Schedule:

Diabetes type	Recommended time of first examination	Recommended follow-up*
Type 1	3-5 years after diagnosis	Yearly
Type 2	At time of diagnosis	Yearly
Prior to pregnancy (type 1 or type 2)	Prior to conception and early in the first trimester	No retinopathy to mild-moderate NPDR - every 3-12 months Severe NPDR or worse - every 1-3 months

*Abnormal findings may dictate more frequent follow-up examinations

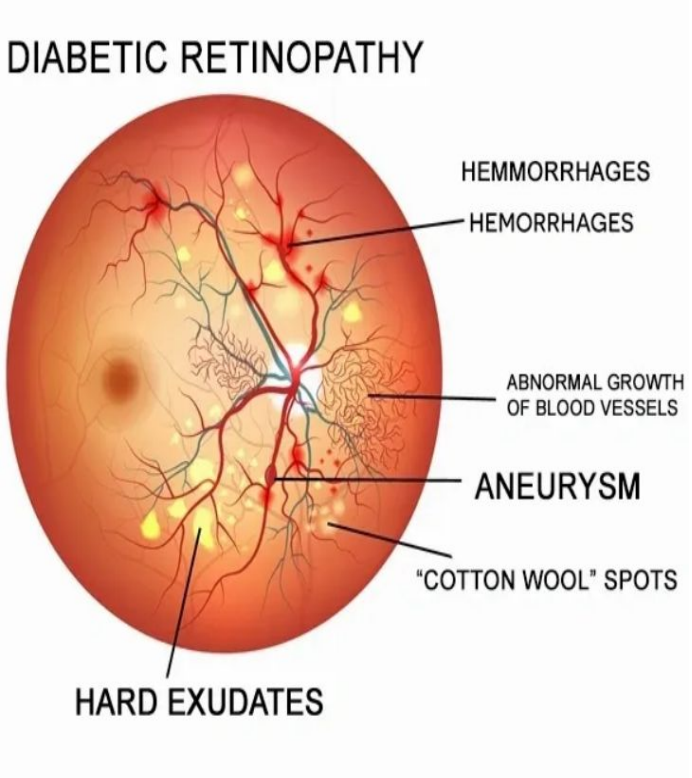
- PDR requires the presence of newly formed blood vessels or fibrous tissue, or both, arising from retina or optic disc and extending along the inner surface of retina or optic sic or into vitreous cavity.

NON-PROLIFERATIVE DIABETIC RETINOPATHY (NPDR)	
NO DR	Review in 12 months
VERY MILD ▪Microaneurysms only	Review most patients in 12 months
MILD ▪Any or all of: microaneurysms, retinal hemorrhages, exudates, cotton wool spots	Review range 6-12 months, depending on severity of signs, stability, systemic factors, and patient's personal circumstances
MODERATE ▪Severe retinal haemorrhages in 1-3 quadrants or mild IRMA ▪Significant venous beading in no more than 1 quadrant ▪Cotton wool spots	Review in approximately 6 months (PDR in up to 26%, high-risk PDR in up to 8% within a year)
SEVERE The 4-2-1 rule- ▪Severe retinal haemorrhages in all 4 quadrants ▪Significant venous beading in ≥2 quadrants ▪Moderate IRMA in ≥1 quadrants	Review in 4 months (PDR in up to 50%, high-risk PDR in up to 15% within a year)
VERY SEVERE ▪≥2 of the criteria for severe	Review in 2-3 months (High-risk PDR in up to 45% within a year)

PROLIFERATIVE DIABETIC RETINOPATHY (PDR)	
MILD-MODERATE ▪New vessels on the disc (NVD) < 1/3 disc area ▪New vessels elsewhere (NVE) < 1/2 disc area	▪Treatment considered according to severity of signs, stability, systemic factors, and patient's personal circumstances ▪If not treated, review in up to 2 months
HIGH-RISK ▪NVD > 1/3 disc area ▪Any NVD with vitreous or preretinal hemorrhage ▪NVE >1/2 disc area with vitreous or preretinal hemorrhage	▪Laser photocoagulation ▪Intravitreal anti-VEGF agents ▪Intravitreal triamcinolone ▪Pars plana vitrectomy ▪Lipid lowering drugs
ADVANCED DIABETIC EYE DISEASE ▪Preretinal (retrohyaloid) and/or intragel hemorrhage ▪Tractional retinal detachment ▪Tractional retinoschisis ▪Rubeosis iridis (iris neovascularisation)	▪Pars plana vitrectomy

Causes of DR:

- Hemorrhages
- Abnormal Growth of blood vessels
- Aneurysm
- Exudates



Diabetic Retinopathy Classification

No disease visible

Mild nonproliferative diabetic retinopathy (NPDR)

Localized swelling of the small blood vessels in the retina (microaneurysms)

Moderate NPDR

Mild NPDR plus small bleeds (dot and blot haemorrhages), leaks (hard exudates) or closure (cotton wool spots) of small blood vessels.

Severe NPDR

Moderate NPDR plus further damage to blood vessels (interetinal hemorrhages, venous beading, intraretinal microvascular abnormalities).

PDR

New vessel formation or vitreous/preretina l hemorrhage or tractional retinal detachment

Objective

Binary classification task

Input Image

DR or NO DR

Objective

Multi class classification

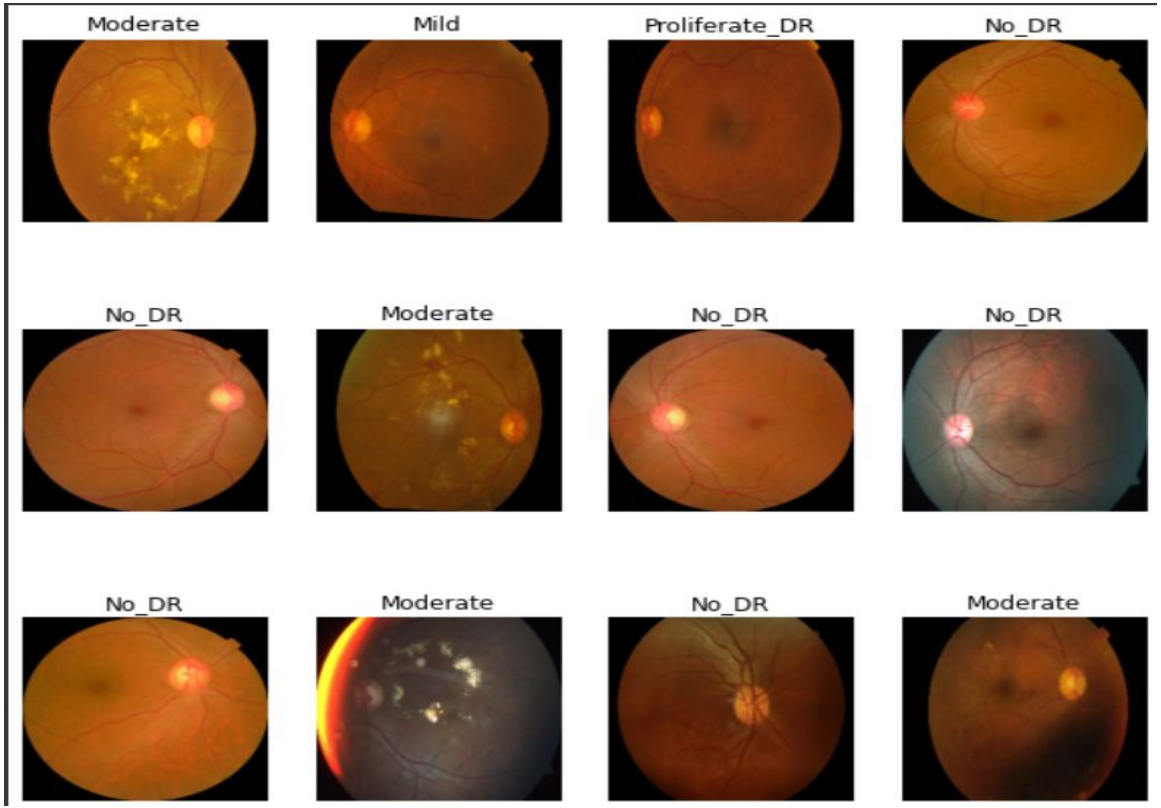
Input Image

DR{Mild, Moderate, Severe, Proliferate} or NO DR

Dataset

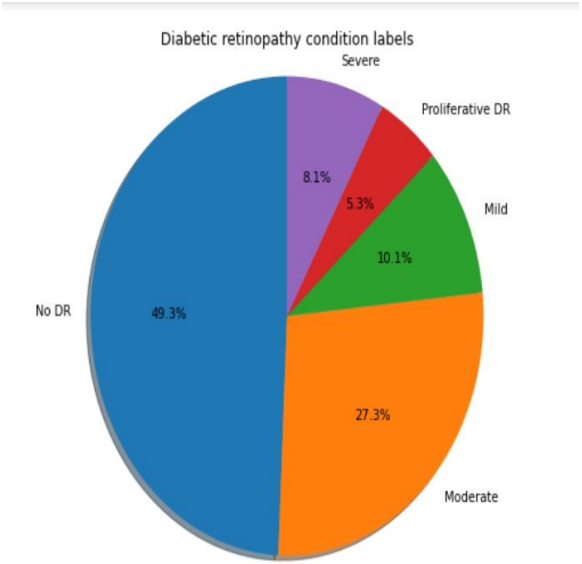
- Total 3667 images
  - 0 - No DR - 1806
  - 1 - Mild - 372
  - 2 - Moderate - 1000
  - 3 - Severe - 193
  - 4 - Proliferative DR - 296

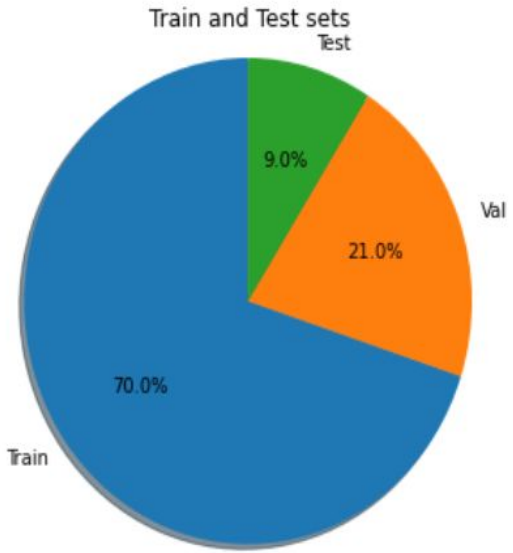
- Shape : 224 x 224 x 3



Citation : https://www.kaggle.com/sovitrath/diabetic-retinopathy-224x224-2019-data

Dataset distribution





Methods

1. Neural Networks for feature extraction + classification
2. Deep CNNs for DR classification
3. Image processing based feature extraction + classification

Method 1 : Feature extraction + external classifier

MobileNet for feature extraction

- Firstly, the features are extracted using the InceptionV3 predefined model.

  - InceptionV3:
    - Inception v3 is a widely-used **image recognition model** that has been shown to attain greater than 78.1% accuracy on the ImageNet dataset.
    - Output size = 28 x28x256
    - Depth = 159
    - Parameters =23.6M

- These features are then given to various classifiers and we measured their accuracy.

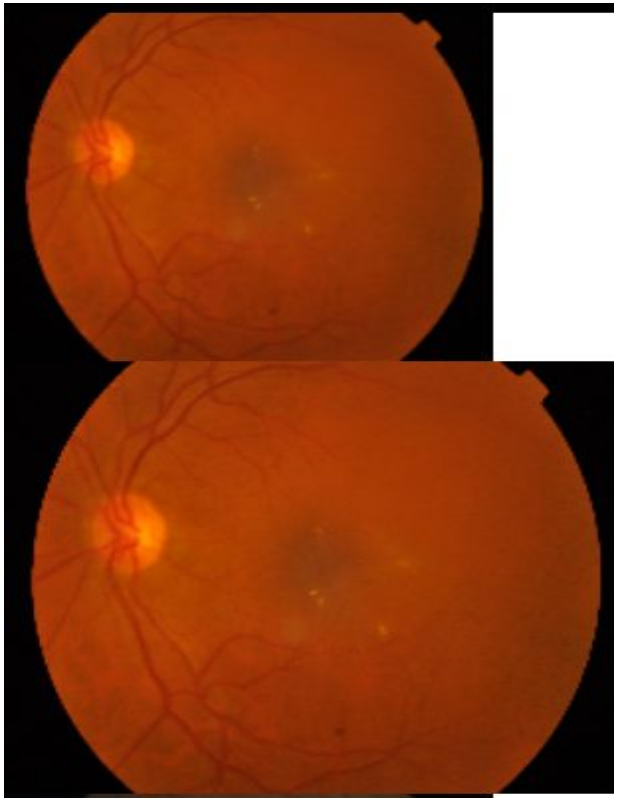
Performance without data augmentation

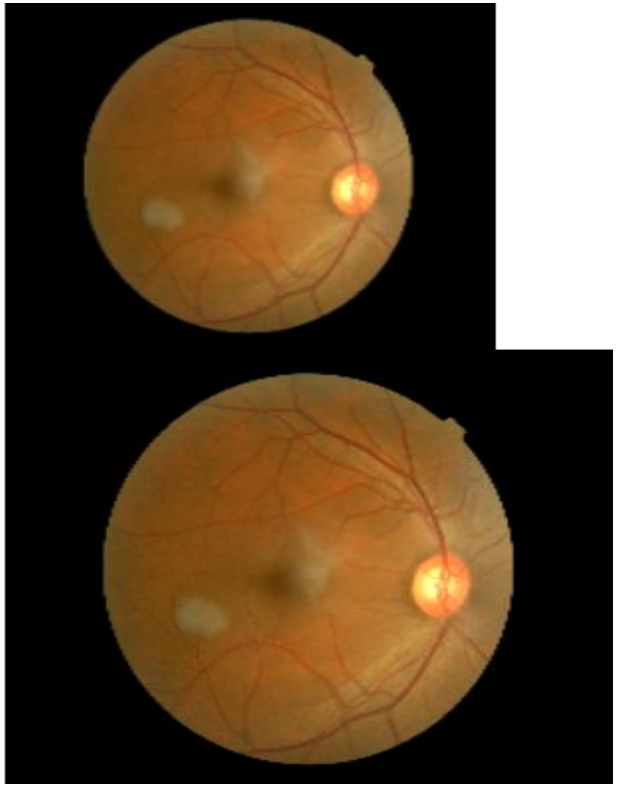
Model	Top 1 Accuracy	Precision	Recall	F1-Score	Kappa score
KNN	0.7848	0.79	0.78	0.78	0.57
SVM	0.7818	0.78	0.78	0.78	0.56
Random Forest	0.8091	**0.81**	**0.81**	**0.81**	**0.62**
Adaboost	0.80	0.8	0.8	0.8	0.6
XGBoost	**0.8121**	**0.81**	**0.81**	**0.81**	**0.62**
DNN	0.7787	0.77	0.77	0.77	0.55

Data Augmentation

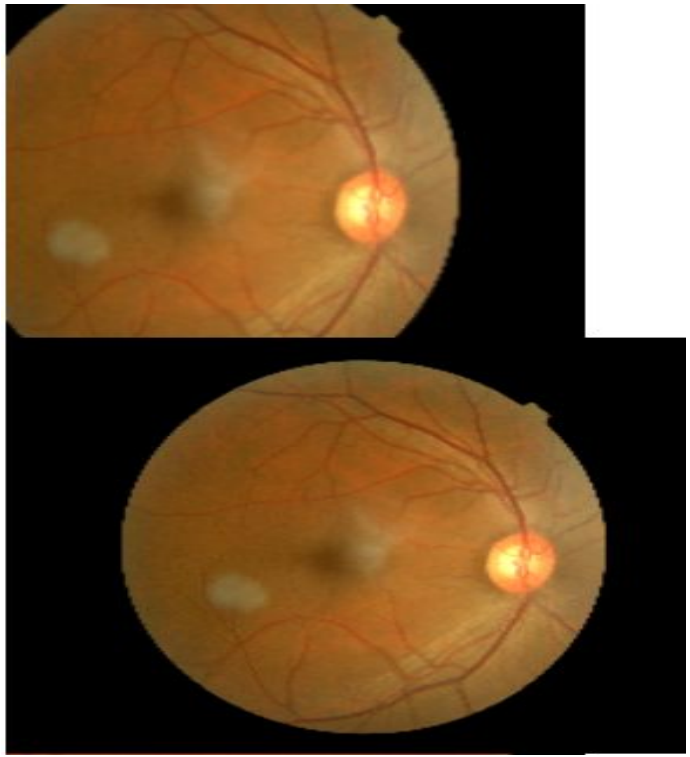
1. Resizing
2. Normalization
3. Gaussian noise
4. Adaptive histogram equalization
5. Grayscale
6. Rotation {90,180}

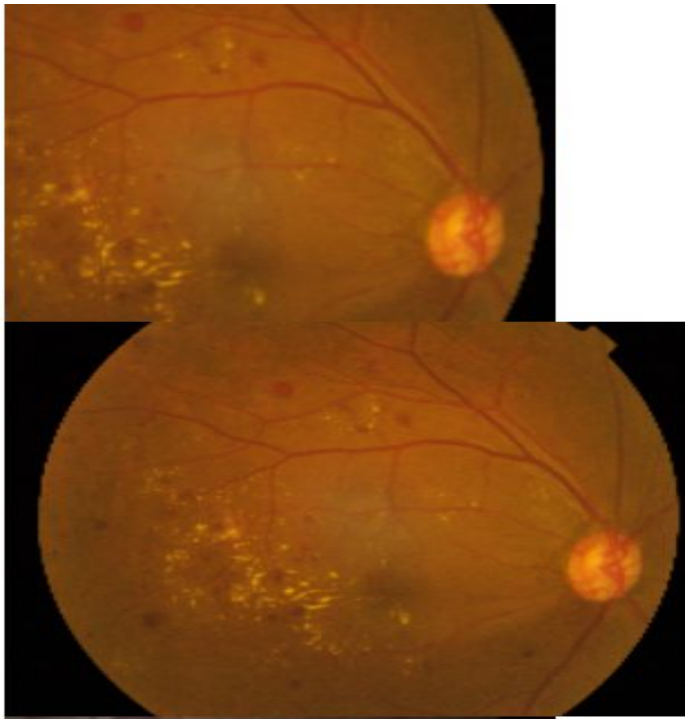
Data Augmentation: Resize



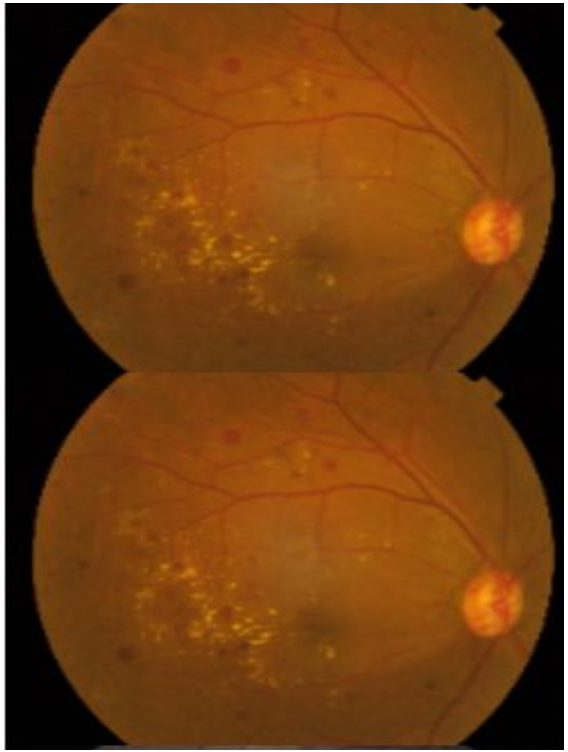


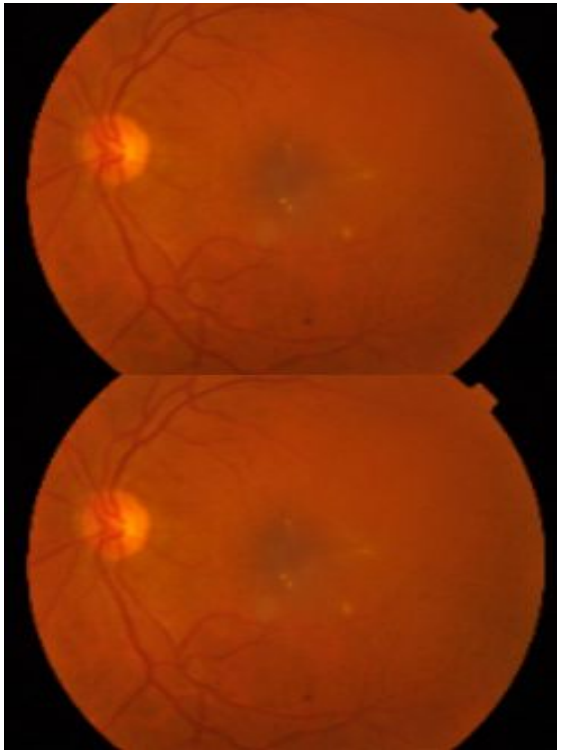
Data Augmentation: Enlarge



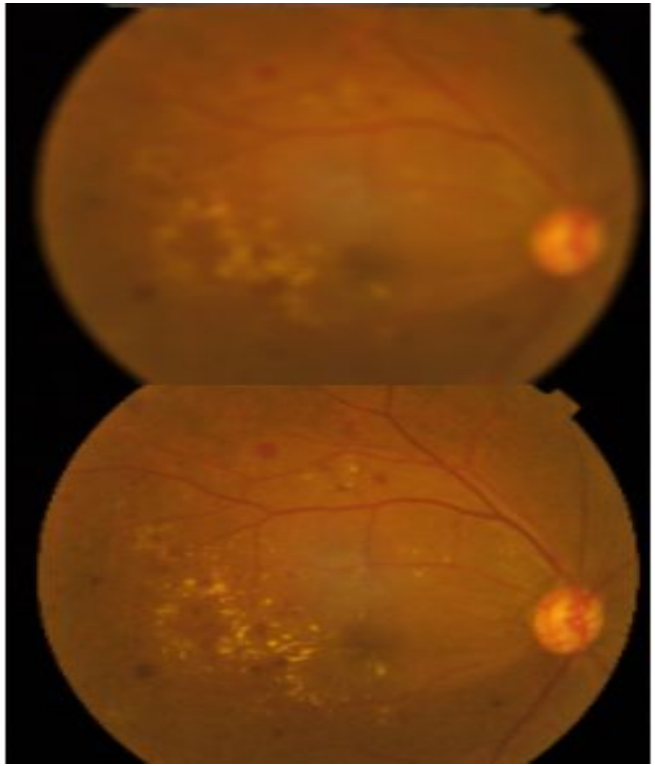


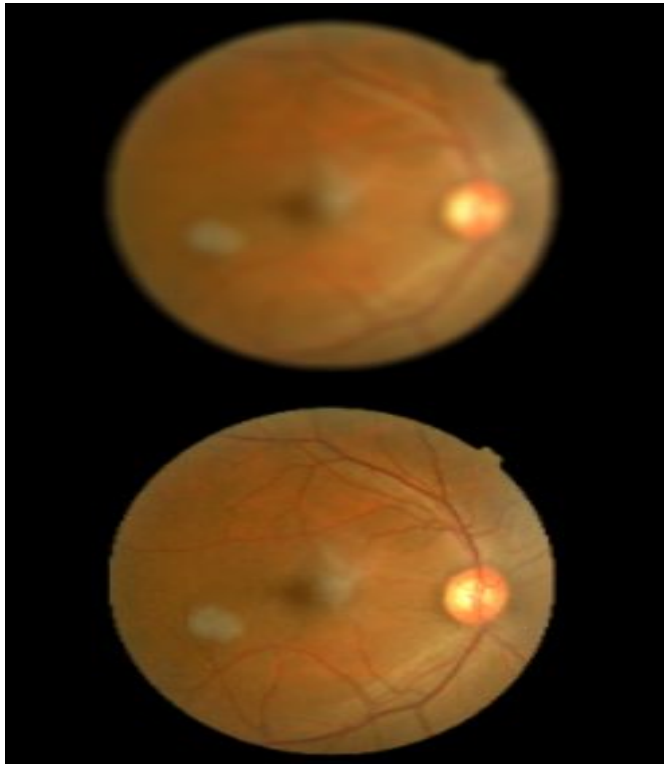
Data Augmentation: Normalize



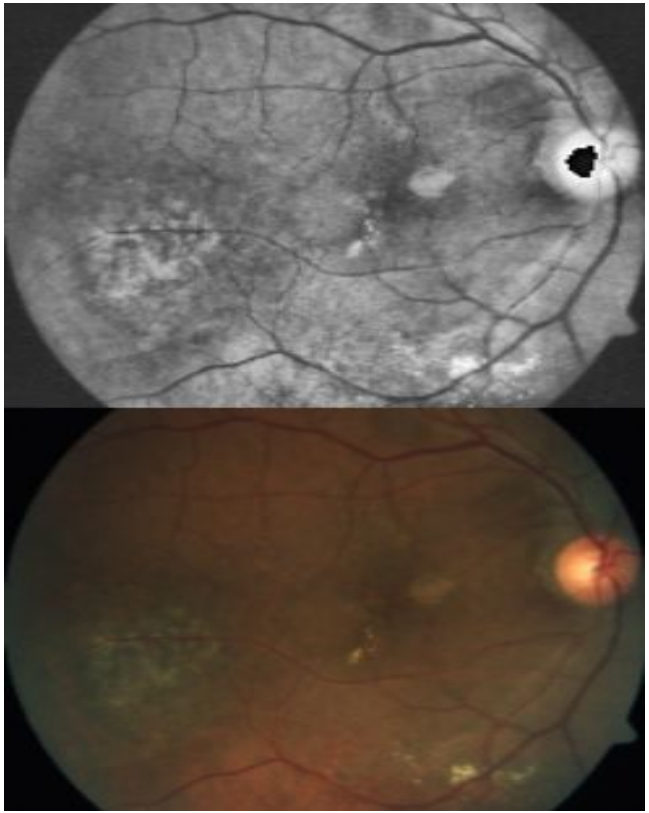


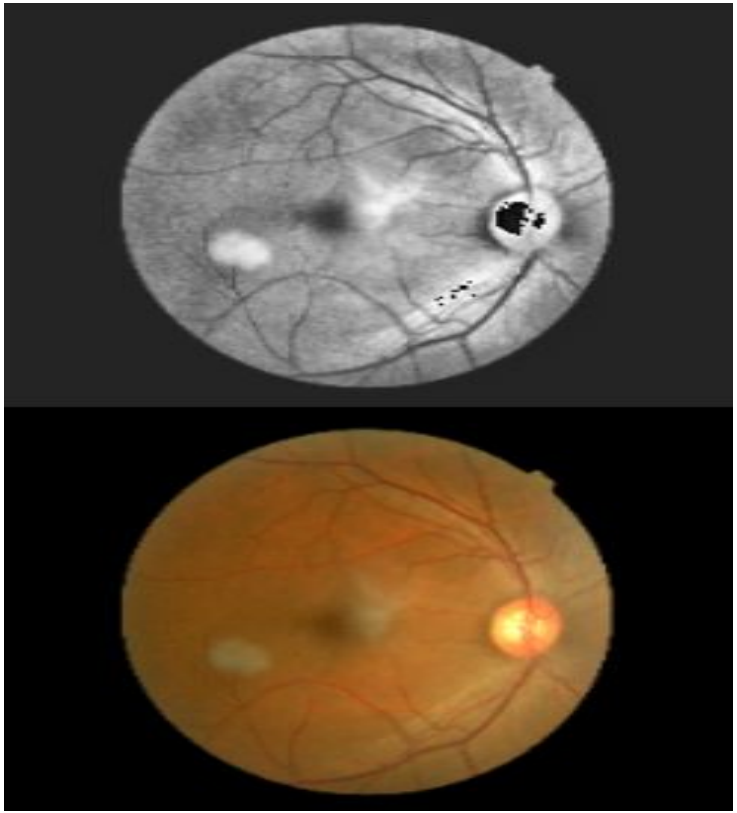
Data Augmentation: Gaussian Noise



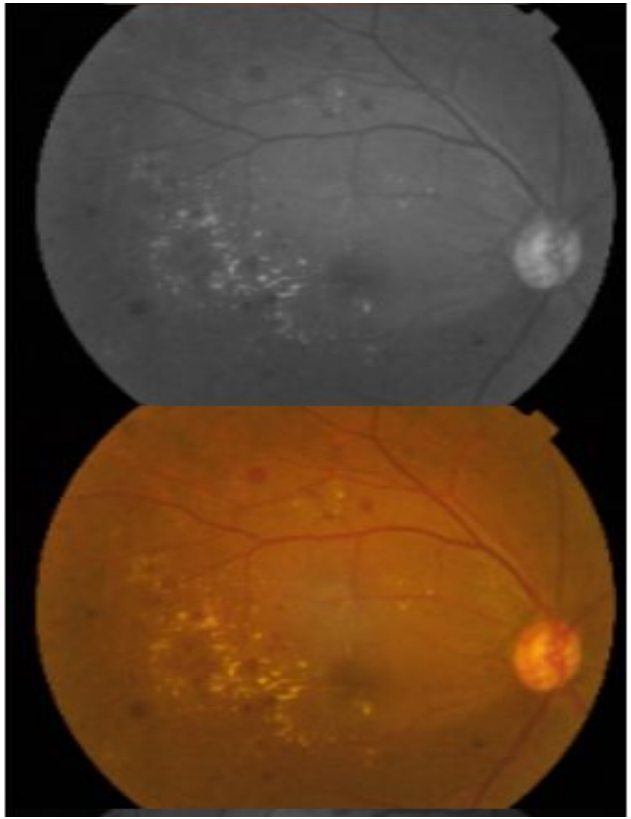


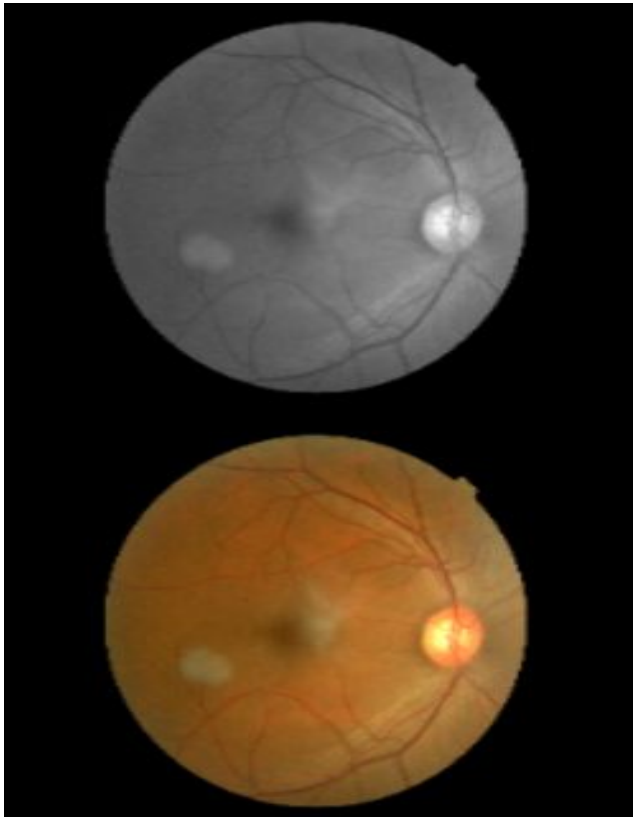
Data Augmentation: CLAHE



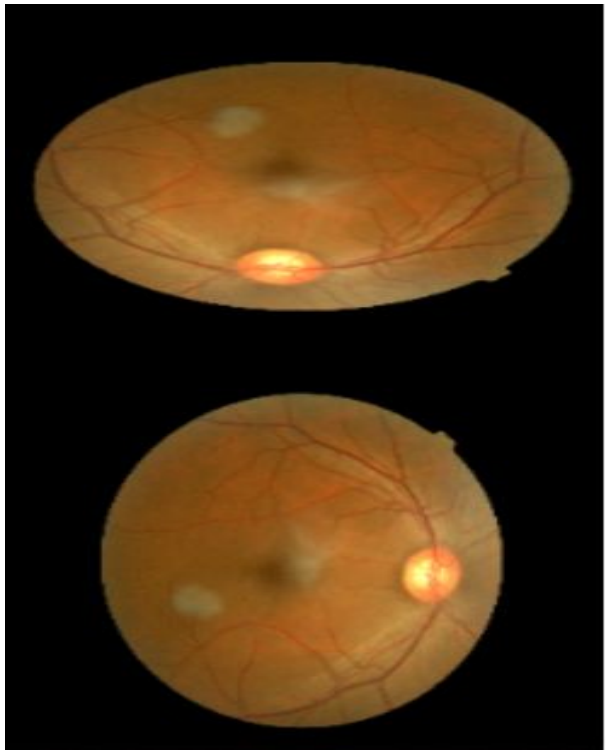


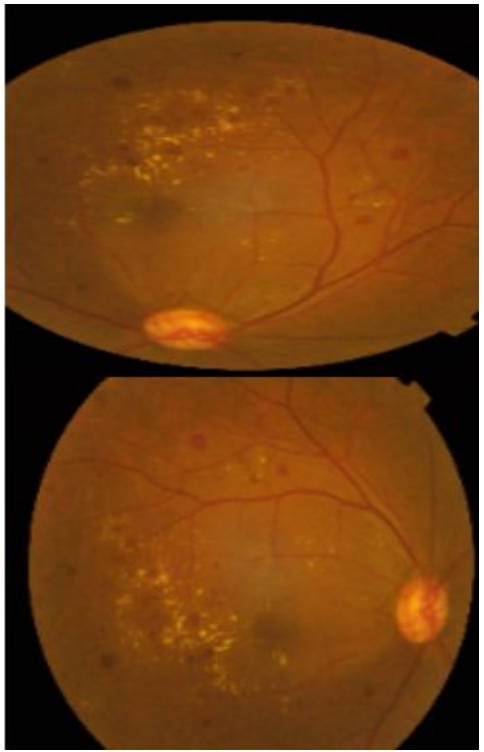
Data Augmentation: Gray Scale



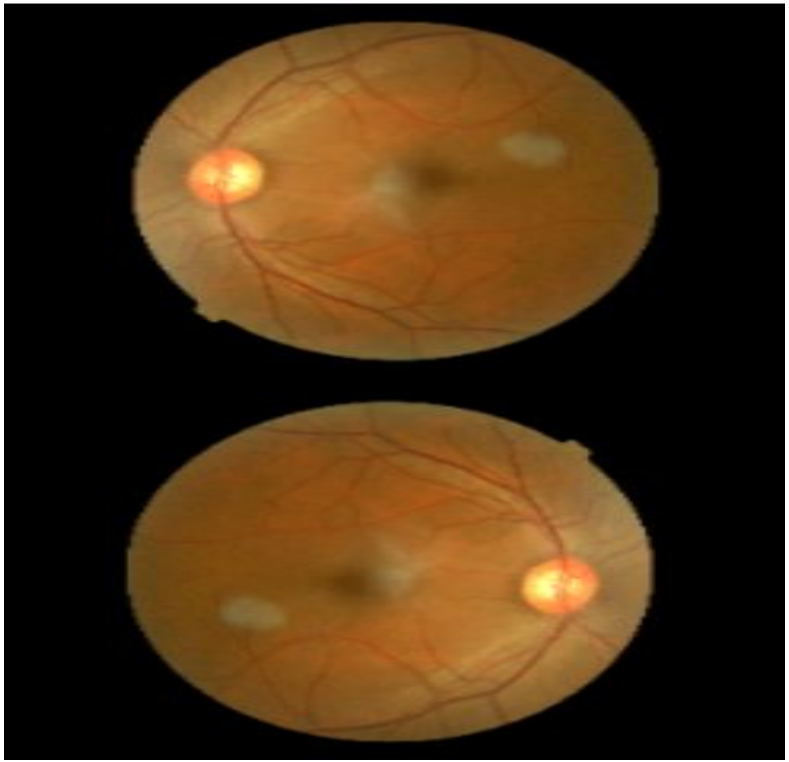


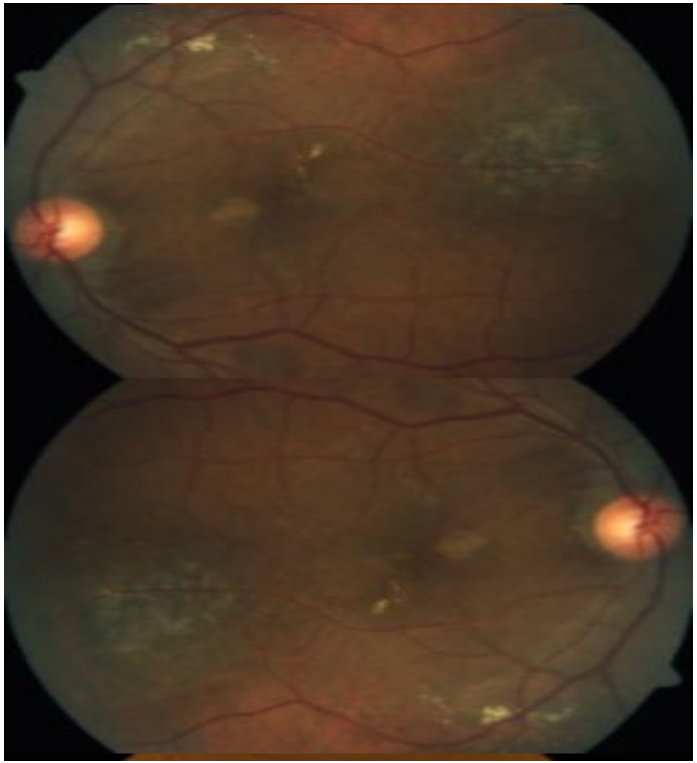
Data Augmentation: Rotate by 90





Data Augmentation: Rotate by 180





The Dataset after Augmentation:

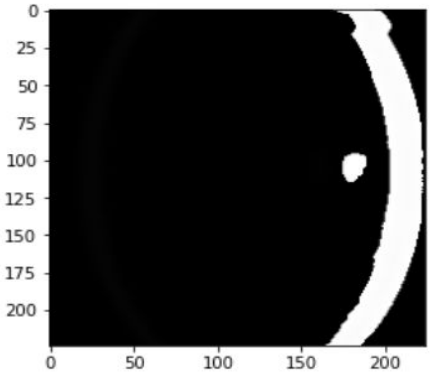
- Total Dataset: 29301
  - Train: 20507
  - Val: 6152
  - Test: 2637

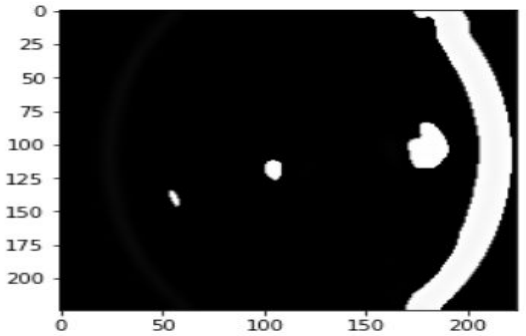
Performance with data augmentation

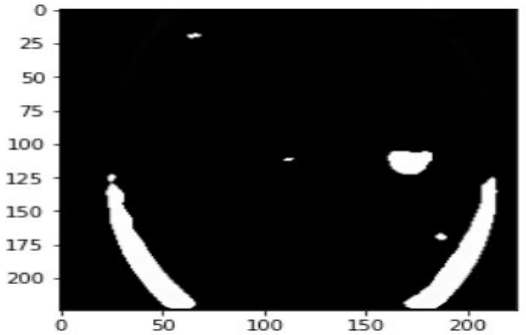
Model	Top 1 Accuracy	Precision	Recall	F1-Score
KNN	0.9064	0.90	0.90	0.90
SVM	0.9102	0.91	0.91	0.91
Random Forest	0.9707	0.97	0.97	0.97
Adaboost	**0.9776**	0.97	0.97	0.97
XGBoost	0.9707	0.97	0.97	0.97
DNN	0.9757	0.97	0.97	0.97

Apply convolve with gray image and guass kernel1D and guass kernel2D:

- As we can see, the first order derivative gives us the edges of the image. The *x*-derivative gives us the vertical edges and the *y*-derivative gives us the horizontal edges.





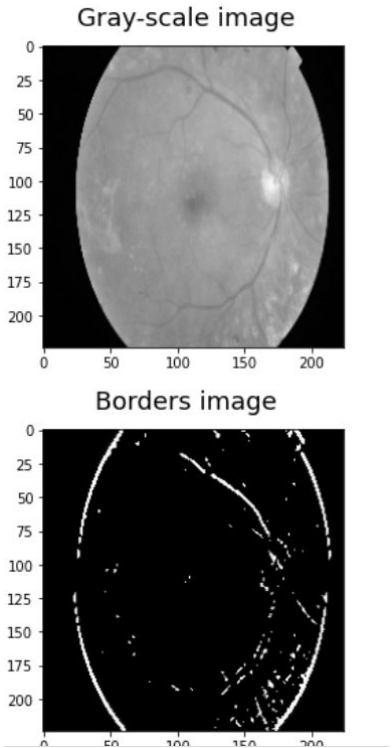


Eye detection

- With sigma= 1.08 and n =35,

convolve of gray image and 2D guass kernel

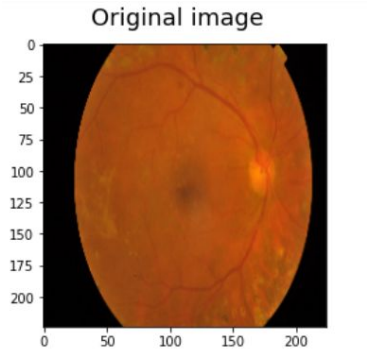
Results into the second image shown.



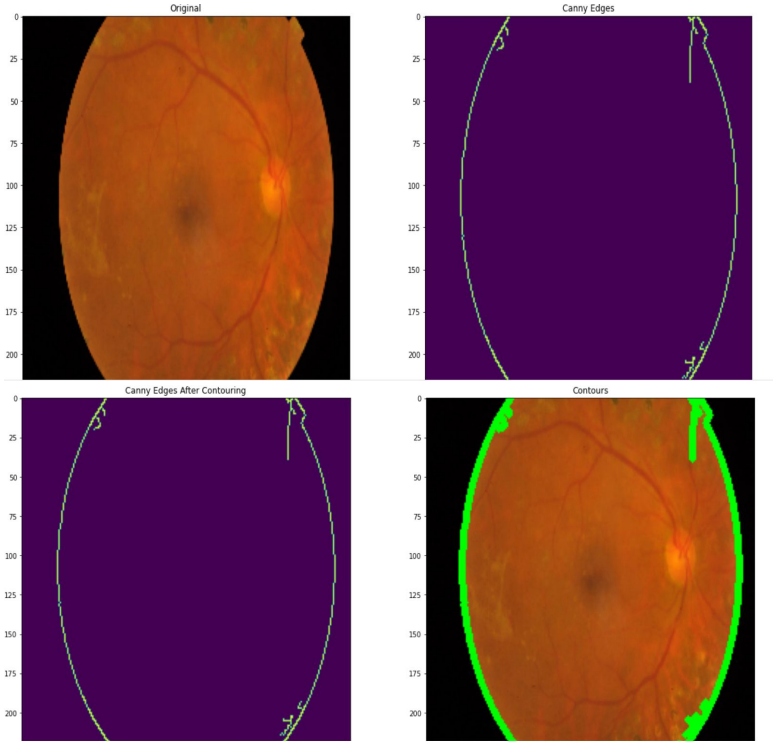
- With sigma= 2.08 and n =35,

convolve of gray img and 2D guass kernel

Results into the second image shown.



- Applying canny edge and contour onto the Original image. Above two 2 diagram shows canny edge applied without contour and later 2 with contour.



Method 2 : Deep neural network based classification

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- Neural Networks are good at learning complex non linear patterns.
- Deep neural networks - stacking of layers in hierarchical manner.
- Since the dataset is small, transfer learning is a better choice than training from scratch
- Data augmentation
  - Horizontal flipping

Method 3 : Deep neural network based classification

1. VGG - VGG19 is a standard 19 layer convnet with that achieved SOTA results on ImageNet in 2013. Commonly used as a feature extractor for downstream tasks.

2. ResNet - ResNet18 is a builds upon VGG network. It utilizes skip connections to jump over layer that help in gradient propagation, local - global feature interactions. ResNet18 has 18 convolutional layers.

Method 3 : Deep neural network based classification

1. EfficinetNet : EfficientNet builds upon basis that appropriate depth, width and resolution of the networks are essential for best performance. It uses a depth, width, resolution scaling factor to develop new architectures.

2. ConvNext : After Visual Transformers, convnext uses the best practices combined from both natural language and vision to create a set of convnext variants. SOTA as of now.

Training Recipe

- Tesla T4 (16GB) GPU
- Cross entropy loss
- Adaptive momentum optimizer
- Learning rate = 3e-4
- Batch size = 128/64/32

Quantitative Results

Binary classification

Model	Top 1 Accuracy	Precision	Recall	F1-Score	False-Classifications (out of 800)
VGG19	0.977	0.98	0.98	0.98	18
ResNet18	0.974	0.97	0.97	0.97	21
EffiecietNet-B0	0.974	0.97	0.97	0.97	21
ConvNext-Tiny	**0.981**	0.98	0.98	0.98	**13**

Quantitative Results

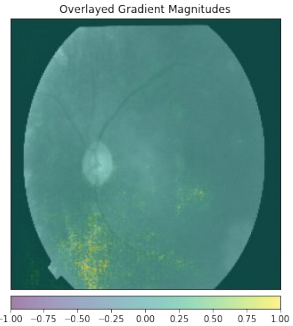
Multi class classification

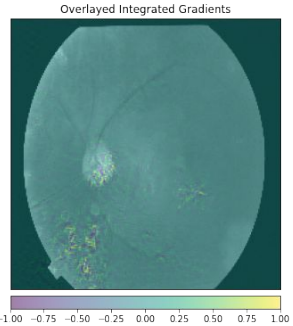
Model	Top 1 Accuracy	Precision	Recall	F1-Score	False-Classifications (out of 704)
VGG19	0.9644	0.96	0.92	0.94	25
ResNet18	0.99	0.98	0.98	0.98	7
EffiecietNet-B0	**0.997**	0.99	0.99	0.99	**2**
ConvNext-Tiny	0.995	0.99	0.99	0.99	3

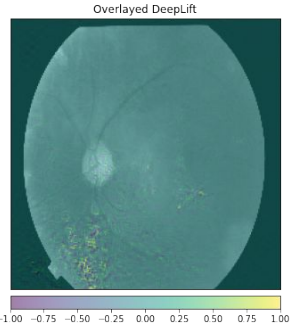
Attributions for Model Understanding

Attributions for Model Understanding

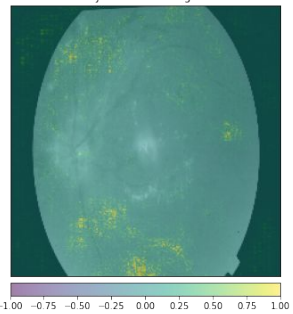
Proliferate DR

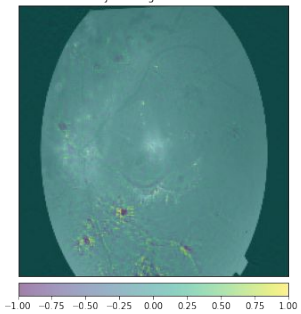


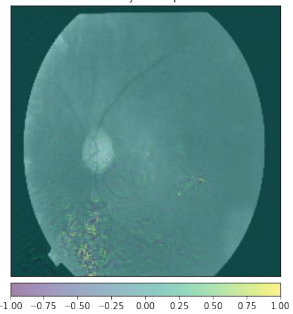




Severe DR

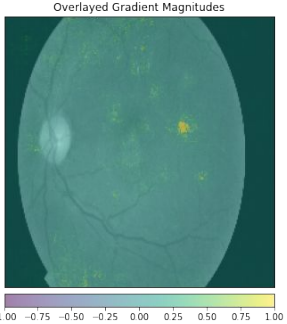


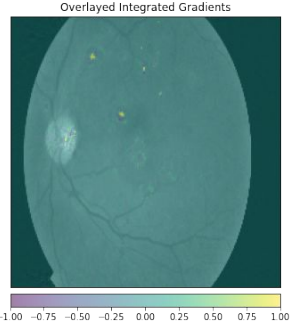


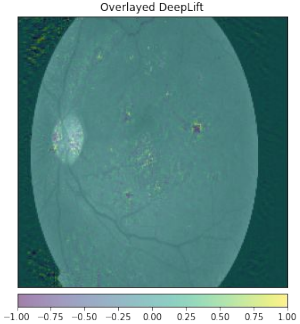


Attributions for Model Understanding

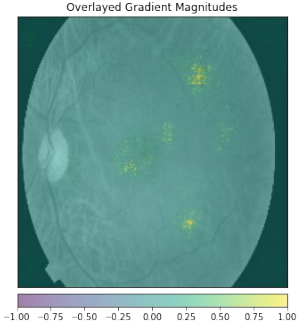
Moderate DR

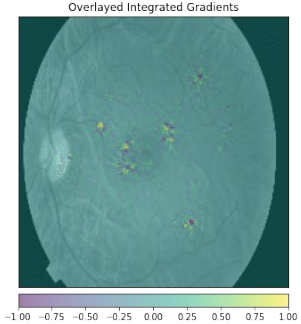


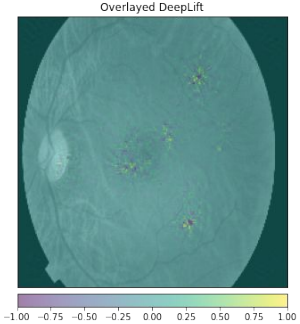




Mild DR







Discussion

1. Objective of project is to do the analysis of DR classification
2. Using existing methods or building upon existing ones
3. We have shown detailed analysis of different methods and their respective performances
4. Deepnets with fine tuning have outperformed normal classifier (with extensive augmentation)

Conclusion

- The obtained results indicate that modern deep networks outperform traditional methods by significant margins (without augmentations)
- Problems
  - Labels are still noisy and varies doctor to doctor, need more accurate labels
  - Network performance increases if that has more precise labels.
  - More robust learning algorithms needed to sustain dataset invariance
  - Expert labels are costly
- Forward directions
  - Weakly supervised / Unsupervised learning algorithms
  - Federated learning to address dataset bias
  -

Save your Vision

1. Check your sugar levels often
2. Stay away from smoking
3. Meet you eye doctor regularly

Thank You