# multiclass retinal fluid segmentation and detection in OCT images using a fully convolutional neural network

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# Objective

- To propose a CNN model  for multiclass fluid segmentation and detection in the retinal OCT images.
- Basically we are trying to detect 3 types of fluid: intraretinal fluid (IRF), subretinal fluid (SRF), and Pigment epithelial detachment (PED)
- Firstly we need to segment the fluid in OCT images , after segmenting the fluid we need to identify it belongs to which category.
- Input provided to us is  OCT volumes, each volume consist of several B-scans, in each B-scans we need to identify the fluid location if present.

# IRF(intraretinal fluid)

- IRF is a hyporeflective space predominantly located in the inner and outer nuclear layers that increases the overall retinal thickness
- It consists of contiguous fluid-filled spaces containing columns of tissue as the arrangement of such spaces is determined by the Müller fibres, which are vertical.
- IRF represents one of the most important variables associated with vision loss.

# Subretinal Fluid (SRF)

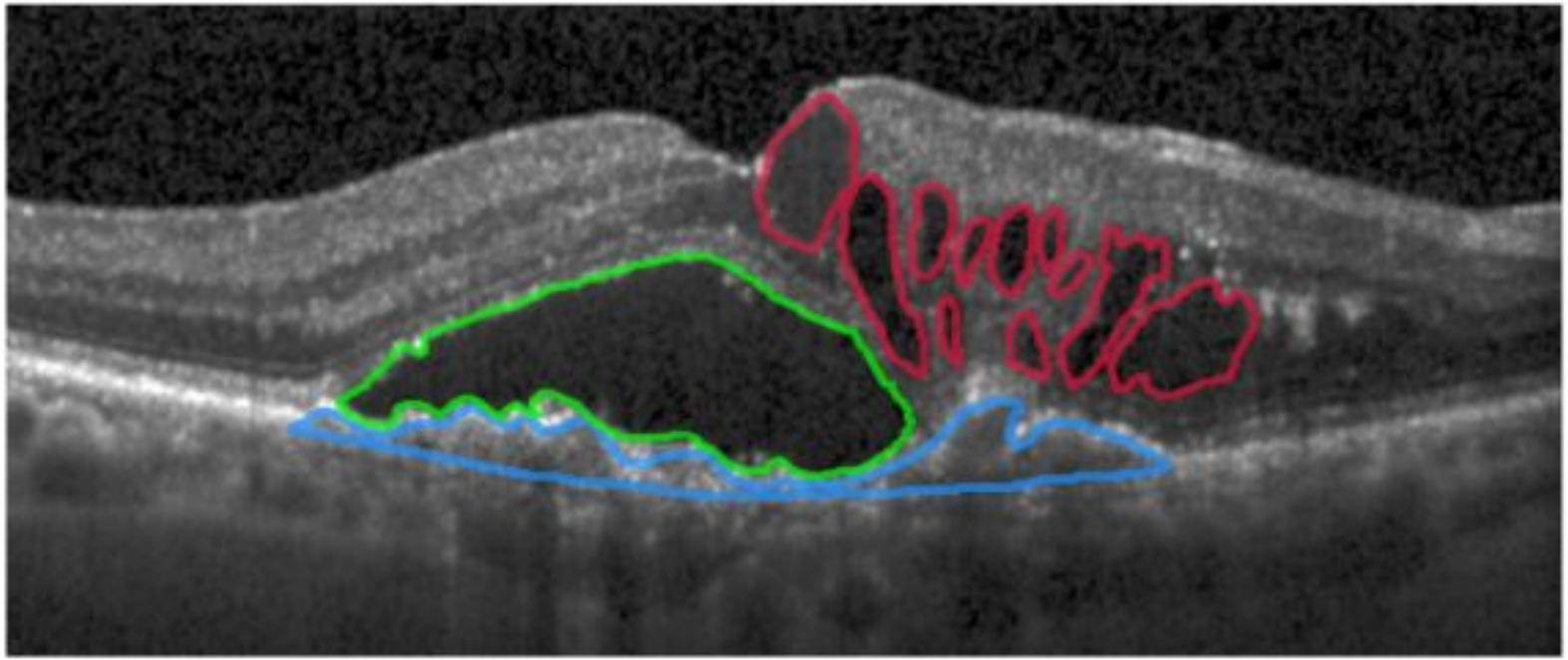
- SRF is a hyporeflective space between the neurosensory retina and retinal pigment epithelium (RPE)
- It corresponds to the accumulation of a clear or lipid-rich exudate in the subretinal space,i.e., between the neurosensory retina and the underlying retinal pigment epithelium (RPE) that nourishes photoreceptors.
- SRF is associated with a possibly favorable visual prognosis in AMD
- AMD(age-related macular degeneration) :AMD is the leading cause of blindness in developed countries affecting older patients.

# Pigment Epithelial Detachment(PED)

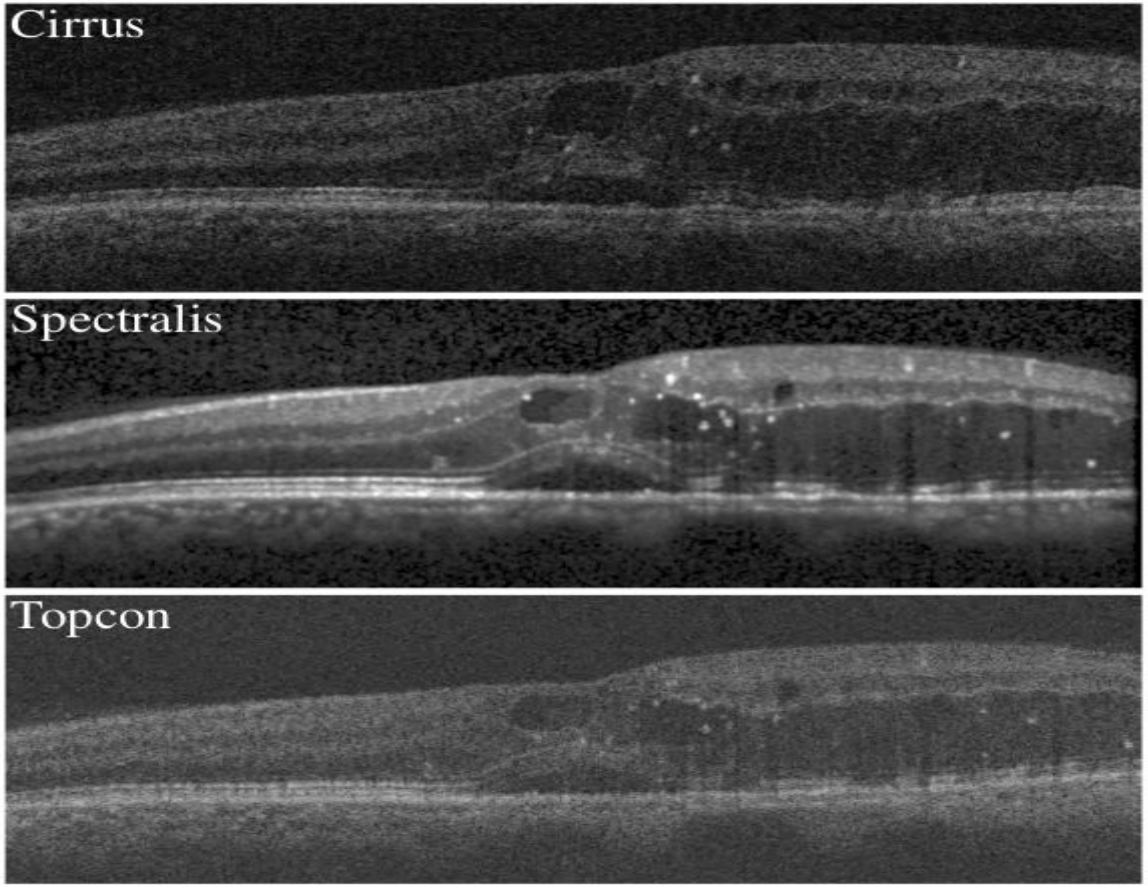
- It represents detachment of the RPE along with the overlying retina from the remaining Bruch’s membrane (BM) due to the accumulation of fluid or material in sub-RPE space.
- The IRF and SRF fluid regions usually show obvious lower intensity compared to nearby retinal tissue, while PED can have similar or even higher intensity.
- PED is composed of three clinical subtypes: serous, fibrovascular, and drusenoid.

# Example of IRF,SRF and PED

Red:IRF Green:SRF Blue:PED



# 3 Different types of OCT Scanner vendor



# Teams with best results in Retouch competition

| Team | Network | Data aug. | Layer seg. | Post-process | 2D/3D |
|---|---|---|---|---|---|
| Helios | U-net | - | - | morphologic | 2D |
| MABIC | U-net | x | - | U-net | 2D |
| NJUST | Faster R-CNN | - | x | 3D smooth | 2.5D |
| RetinAI | U-net | x | x | - | 2D |
| RMIT | U-net + adversarial | x | - | median filt. | 3D |
| SFU | U-net | x | x | rand. forest | 2D |
| UCF | ED-ResNet | x | - | graph-cut | 2.5D |
| UMN | CNN | - | x | morphologic | 2D |

'x' denotes the use of data augmentation or retinal layer segmentation

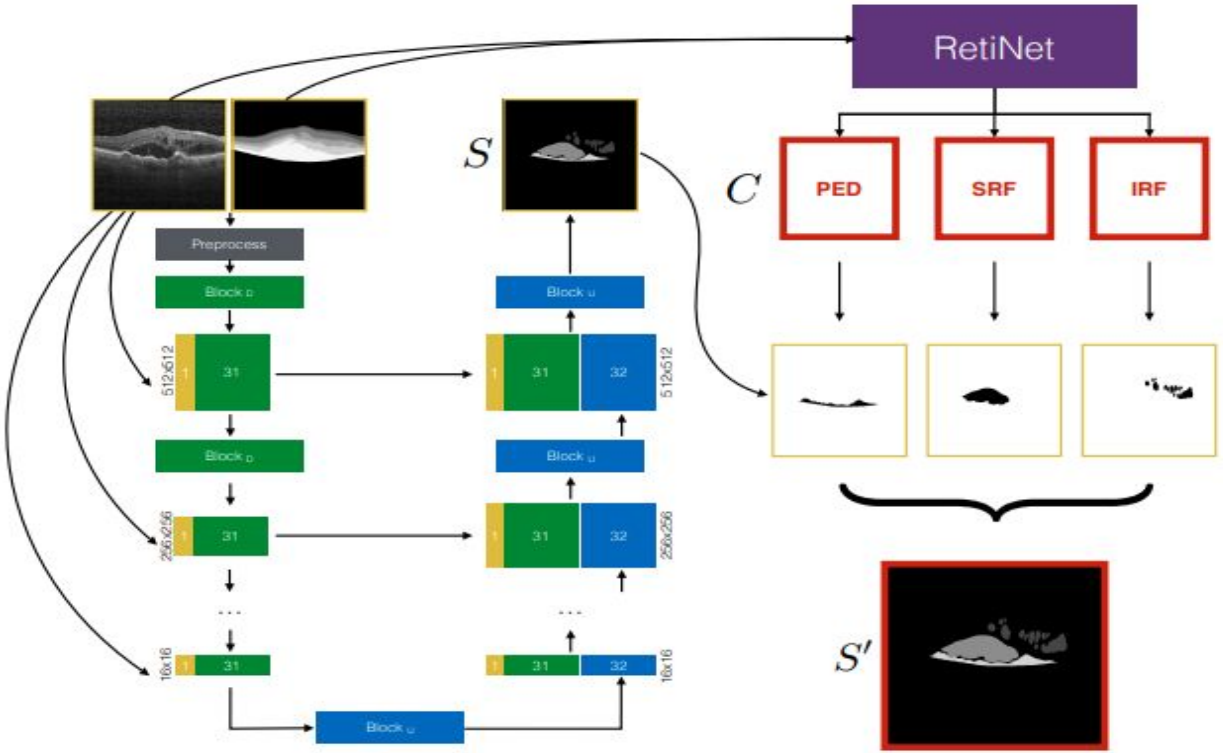
# SFU model

- Preprocessing :(Noise Removal) reduce the effect of speckle, motion-corrected intensity B-scans in each volume were smoothed by 3D Bounded variation (BV). Then, 3D graph-cut based algorithm was applied to segment the internal limiting membrane (ILM) and the Bruch's membrane (BM)(layer segmentation).
- Multi-class fluid pixel segmentation :U-net is used to segment each pixel into background, IRF, SRF and PED.
- relative distance map was concatenated to the intensity of each , B-scan as the second channel of input image.
- Softmax cross entropy as loss function.
- Data Augmentation:flip, rotation and zooming is used for data augmentation.
- Post-processing: Random forest classifier is used.

# Retina AI

- a Branch Residual U-Net (BRUNet) is used for image segmentation.
- Preprocessing: in this model for preprocessing more focus is given to layer segmentation.
- Data-Augmentation: horizontal flip, shear, rotation, shift and Gaussian noise is performed.

# Retinal AI


RetiNet
S
C
PED
SRF
IRF
Preprocess
Block d
Block u
512x512
256x256
16x16
31
32
S'

# UCF

- Preprocessing:OCT volume is smoothed with a three-dimensional Gaussian kernel in order to remove speckle. Intensity of each bscan is then rescaled.
- bicubic downsampling is used to resize the images.
- Cropping is done in order to minimize the background area.
- Data Augmentation: myopic warping
- CNN network:ResNet
- Post-Processing:graph-cut algorithm is used

# Retouch Competition results(detection leaderboard)

TABLE V
DETECTION TASK LEADERBOARD WITH AUC VALUES FOR EACH FLUID TYPE.

| Rank Sum | Team | IRF | SRF | PED |
|---|---|---|---|---|
| 3 | SFU | 1.00 | 1.00 | 1.00 |
| 6 | UCF | 0.94 | 0.92 | 1.00 |
| 8 | Helios | 0.93 | 1.00 | 0.97 |
| 10 | MABIC | 0.86 | 1.00 | 0.97 |
| 10 | RMIT | 0.71 | 0.92 | 1.00 |
| 11 | RetinAI | 0.99 | 0.78 | 0.82 |
| 11 | UMN | 0.91 | 0.92 | 0.95 |
| 13 | NJUST | 0.70 | 0.83 | 0.98 |
| | Majority Vote | 1.00 | 1.00 | 1.00 |

# Retouch Competition results(segmentation leaderboard)

| Rank Sum | Team | IRF | | SRF | | PED | |
|---|---|---|---|---|---|---|---|
| | | DSC | AVD | DSC | AVD | DSC | AVD |
| 39 | SFU | 0.82 (0.19) | 0.030 (0.036) | 0.75 (0.30) | 0.041 (0.089) | 0.74 (0.24) | 0.140 (0.154) |
| 59 | UMN | 0.70 (0.20) | 0.088 (0.131) | 0.71 (0.33) | 0.032 (0.058) | 0.77 (0.23) | 0.119 (0.207) |
| 64 | MABIC | 0.78 (0.22) | 0.027 (0.032) | 0.66 (0.32) | 0.064 (0.123) | 0.70 (0.29) | 0.167 (0.169) |
| 73 | RMIT | 0.73 (0.20) | 0.078 (0.079) | 0.70 (0.31) | 0.046 (0.094) | 0.69 (0.25) | 0.245 (0.290) |
| 74 | RetinAI | 0.74 (0.19) | 0.039 (0.054) | 0.67 (0.33) | 0.079 (0.147) | 0.71 (0.29) | 0.189 (0.416) |
| 88 | Helios | 0.63 (0.19) | 0.048 (0.064) | 0.68 (0.30) | 0.059 (0.103) | 0.66 (0.26) | 0.297 (0.503) |
| 120 | NJUST | 0.57 (0.21) | 0.107 (0.124) | 0.53 (0.34) | 0.103 (0.169) | 0.63 (0.27) | 0.253 (0.380) |
| 130 | UCF | 0.49 (0.20) | 0.276 (0.319) | 0.54 (0.33) | 0.112 (0.140) | 0.63 (0.24) | 0.280 (0.285) |
| | Majority Vote | 0.83 (0.17) | 0.027 (0.036) | 0.79 (0.31) | 0.027 (0.048) | 0.80 (0.24) | 0.095 (0.110) |

# Teams methodology in Retouch

| Team | Network | Data aug. | Layer seg. | Post-process | 2D/3D |
|---|---|---|---|---|---|
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# Fluid segmentation in Neutrosophic domain(Dec 2019)

- Only fluid segmentation is done ,no detection is performed.
- Uses neutrosophic C-means which comes under Neutrosophic domain.
- No use of Deep learning model.
- Tested on OPTIMA Cyst Segmentation Challenge.
- Compared and outperformed all other existing neutrosophic domain methods.
- Dice coefficient of model is 82.23 while of SFU(leader of retouch compitition) is nearly 77.

# Fully Convolutional Networks for Fluid Segmentation in Retina Images(19 feb 2020)

- Only fluid segmentation is done ,no detection is performed.
- First region of interest (ROI) segmentation is done in preprocessing
- ROI is done using graph shortest path layer segmentation
- FCN model is used to perform segmentation of fluid on images after performing ROI
- For training and testing 600 OCT scans of 24 subjects collected from University of Minnesota is used.
- model is compared with neutrosophic graph cut (NSGC) , graph cut(GC)  and kernel graph cut (KGC) methods.
- It showed the avg dice coefficient of 86.00.

# Deep learning architectures analysis for age-related macular degeneration segmentation on OCT scans(may 2019)

- Both fluid segmentation and detection is performed on all three liquids.
- They showed  how a patch-based approach could push the performance for each method of Retouch.
- In preprocessing Denoising (BM3D) and resizing is done
- Models trained on patch-based approach are UNET, FCN,Segnet and Deeplab.
- In post processing median filter and morphological operations is being used.
- All models trained on Retouch dataset and tested on Optimus challenge dataset
- Out of all patched UNET and Deeplab architecture appeared to be best and have dice coefficient of 0.85.

# Pathological Retinal Region Segmentation From OCT Images Using Geometric Relation Based Augmentation(March 2020)

- Image segmentation is performed ,no fluid detection is performed.
- In preprocessing new kind of data augmentation technique is performed known as Geometry-Aware Shape Generative Adversarial Network (GeoGAN).
- First image and its mask is fed to Spatial transformer network (STN), which works on idea of GeoGAN and produces new augmented images.
- Then Unet and other versions of unet architecture is used for fluid segmentation.
- It is trained and tested on Retouch dataset.
- GeoGAN have DSC of 0.906(only on Spectralis dataset) and average DSC value of The average DSC value of 0.893

# Results comparison

| Models | DSC value |
|---|---|
| GeoGAN | 0.893 |
| Patched Unet | 0.85 |
| Graph shortest path+FCN | 0.86 |
| Neutrosophic domain | 0.82 |
| SFU | 0.77 |
| UMN | 0.72 |