A Deep Learning System For Sickle Cell Retinopathy Detection Using Retinal OCT Images From Children With Sickle Cell Disease

Jing Jin[1], Ashuta Bhattarai[2], Robin E. Miller[1], Edward A. Kolb[1], Chandra Kambhamettu[2]

[1]Nemours Children's Hospital, Delaware

[2] Video/Image Modeling and Synthesis (VIMS) Lab, Dept. of Computer and Information Sciences, University of Delaware

INTRODUCTION

- Sickle cell disease (SCD) causes vascular occlusion leading to **tissue damage** and **volume loss**.
- B-scan (cross section) retinal optical coherence tomography (OCT) images of SCD patients show **retinal damage** as inner retinal thinning [1].
- A normal landmark, **fovea**, is a pitted invagination located at the center of the posterior retina, where the inner retina is the thinnest.
- Early and subclinical sickle cell retinopathy (SCR) is frequently detected by retinal OCT. Characteristic injuries are most frequently present in areas just temporal to the fovea (Fig. 1).
- This project utilizes a deep learning method to detect **changes in retinal thickness** due to SCR and differentiate it from fovea using retinal OCT from children with SCD.

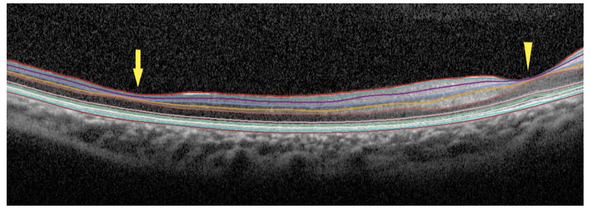


Fig. 1: SCR and fovea in an OCT B-scan

HIGHLIGHTS

- SCD causes inner retinal thinning.
- SCR can be diagnosed by examining retinal OCT images.
- We collected and annotated OCT images of children with SCD.
- We used the You Only Look Once (YOLO) [2] network to automatically detect SCR and separate it from fovea.
- Our model achieves a detection mAP of 87% in SCR and 96% in fovea.

METHODS

- Children with SCD underwent ophthalmologic examination at Nemours Children's Hospital, Delaware between September 2015 and January 2022.
  - 38 patients (18 male, 23 SS, 9 SC, 3 Sβ+, 3 Sβ0)
  - Age 13.50 ± 4.64, range 5.25 to 20.26 years
- Retinal OCT were obtained using SPECTRALIS (Heidelberg Engineering).
  - 4719 B-scans from 153 OCT studies
  - SCR b-box: 1430 instances in 905 B-scans
  - Fovea b-box: 639 instances in 639 B-scans
- We used a **deep learning-based object detection** approach to identify SCR and fovea instances.

$$mAP = \frac{1}{N}\sum_{k=0}^{N} AP_k$$

Where, AP_k is average precision of class k and N is the number of classes

- **Fovea** and **SCR** were annotated with bounding-box.
- Dataset was divided into 5 equal sets for **5-fold cross validation.**
- **YOLO** v4 [2], a grid-based object detection algorithm, was applied.
- Five models, each using about 3780 training and 939 validation images for over 1000 epochs, were trained.
- Tesla V100 GPU was used to train.
- Training loss was calculated with **binary cross entropy** and **focal loss.**
- Model performance was tested with **mean average precision (mAP).**
- mAP was calculated using intersection over union between annotated and predicted bounding boxes.

RESULTS

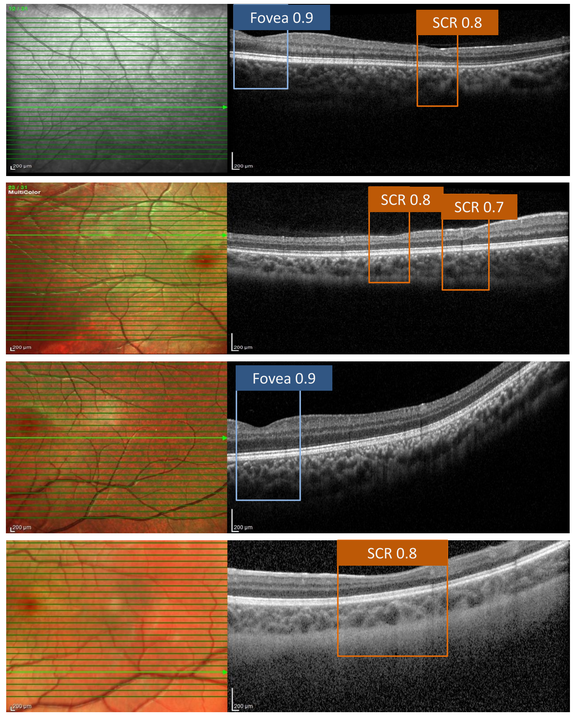
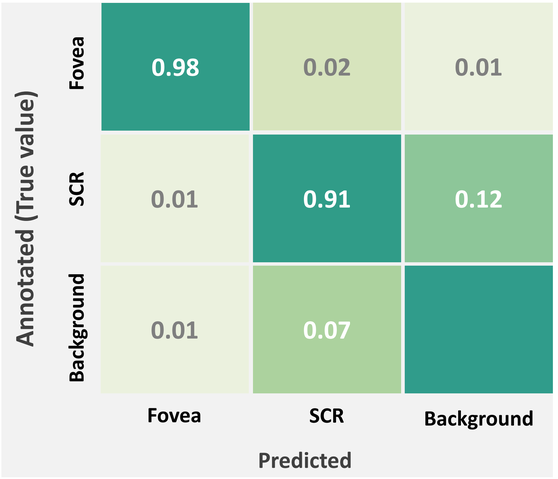


Fig 2: Results of test dataset with confidence score

Cross Validation (Fovea, SCR)			
Folds	mAP@.5	Sensitivity	Specificity
1	(0.97, 0.85)	(0.98, 0.84)	(0.99, 0.93)
2	(0.94, 0.90)	(0.96, 0.89)	(0.98, 0.96)
3	(0.93, 0.89)	(0.95, 0.90)	(0.99, 0.96)
4	(0.96, 0.86)	(0.98, 0.85)	(0.98, 0.94)
5	(0.98, 0.85)	(0.98, 0.87)	(0.99, 0.96)
mean	**(0.96, 0.87)**	**(0.97, 0.87)**	**(0.99, 0.95)**

CONFUSION MATRIX



CONCLUSIONS

- **High precision SCR detection** was achieved using YOLO deep learning object detection network
- Accurate distinction occurred between SCR and fovea
- Future research:
  - **Volumetric OCT** analysis for better detection
  - Analyze OCT scans of **re-visiting patients** to predict SCR progression
- Further details available at: www.bigdatavision.org/octimg/

REFERENCES

1. Jin J, Miller R, Salvin J, et al. Funduscopic examination and SD-OCT in detecting sickle cell retinopathy among pediatric patients. J AAPOS 2018;22:197-201.e1.
2. Bochkovskiy A, Wang C, Liao HM. Yolov4: Optimal speed and accuracy of object detection. CoRR, 2020; abs/2004.10934, 2020.

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