Inference for Spatial Trends

Ngai Hang CHAN

Email: nhchan@sta.cuhk.edu.hk
The Chinese University of Hong Kong
Shatin, NT, Hong Kong

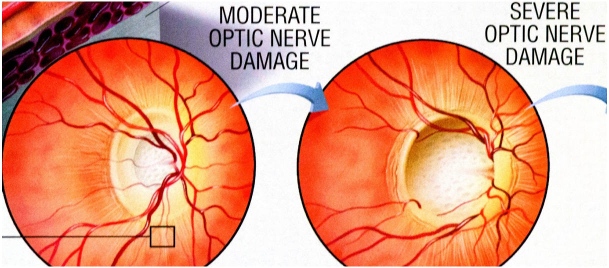
Joint work with Rongmao Zhang, Clement Tham and HKEH
Research supported in part by grants from HKSAR-RGC-GRF and HKSAR-RGC-TBRS

Overview

Introduction: What is Glaucoma?

Glaucoma is a specific type of optic neuropathy with characteristic, progressive, and irreversible optic nerve fiber loss:

- Characteristic structural change in optic nerve head: Glaucomatous Optic Neuropathy (GON).
- Characteristic functional loss - visual field loss (GVFL).



Introduction: Vision of Glaucoma Patients

Introduction: Glaucoma

Glaucoma is the foremost cause of irreversible blindness. Since vision loss from glaucoma cannot be reversed, improved screening and detection methods for glaucoma are essential to preserve vision and life quality.

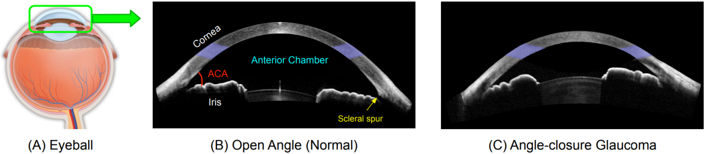
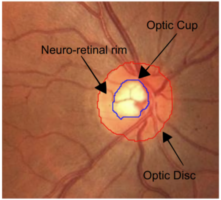


Fig. 1. The example of (B) open angle and (C) angle-closure. The narrow anterior chamber angle (ACA) blocks drainage channels of aqueous fluid.

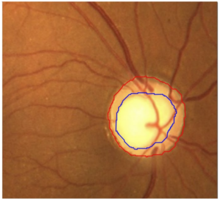
A common type of glaucoma is angle-closure, where the anterior chamber angle (ACA) is narrow as shown in Figure 1, leading to blockage of drainage channels that results in pressure on the optic nerve.

Common Methods of Glaucoma Diagnosis: Fundus Image

In a fundus image, the optic disc can be visually separated into two zones, a bright and central zone called **optic cup** and a peripheral part called **neuro-retinal rim**. See figure a.



a



b

While the optic disc (OD) and cup are present in all individuals, an abnormal size of the cup with respect to the optic disc is a characteristic of a glaucomatous eye, as it is shown in figure b. For that reason, some works in the literature focus on the Cup/Disc ratio (CDR) calculation. This measurement is commonly used as a glaucoma indicator, which expresses the vertical diameter proportion of the optic disc and the cup.

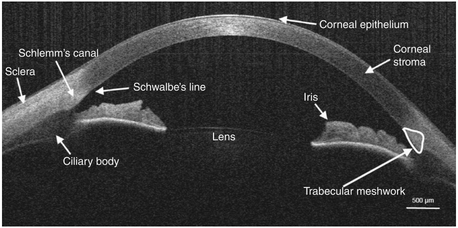
Drawbacks of CDR measurement

Subjective estimation of the CDR has long been used to quantify the degree of cupping in glaucoma in the clinical setting.

However, using this method to detect early glaucomatous signs and progressive glaucomatous changes is extremely difficult due to poor sensitivity and high inter and intraobserver variability.

Common Methods of Glaucoma Diagnosis: AS-OCT

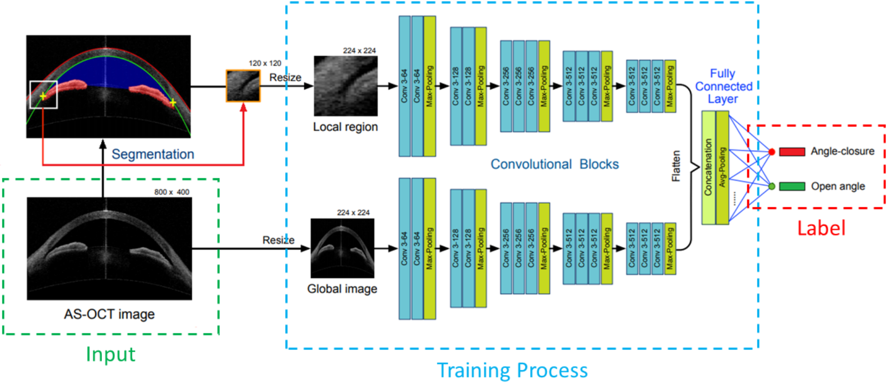
Anterior Segment Optical Coherence Tomography (AS-OCT) is useful as an adjunct to gonioscopy as well as a substitute when gonioscopy is not feasible due to corneal pathology or lack of patient co-operation.



Traditional methods segment the AS-OCT image and then extract the representation based on clinical parameters or visual features which are frequently used for angle-closure classification. Recently, deep learning is introduced for the purpose of gaining more discriminative representations on different regions for glaucoma screening prediction.

Glaucoma Diagnosis by Deep Learning

- Supervised learning: Inputs (x, y) = (images, labels).
- Training weights (parameters) based on ResNet, which is a popular architecture in convolutional neural network.



Glaucoma Diagnosis by Deep Learning

- This deep learning architecture includes two parallel streams to obtain the representations for different clinical regions in an AS-OCT image, namely the global fundus image and local disc region.
- Convolutional blocks aim on extracting the features of images.
- The objective of a fully connected layer is to take the results of the convolution process and use them to classify the image into a label (e.g. angle-closure/open angle). In fact, the last step in fully connected layer is a logistic regression (in binary classification sample).

Idea:

Instead of training via convolutional blocks, use spatial trend detection model to detect change points and learn the structures of images, thereby to identify features which are helpful in glaucoma diagnosis.

Common Methods of Glaucoma Diagnosis: SD-OCT

It is widely recognized that glaucoma is a multifactorial optic neuropathy that is characterized by continuous processes, including progressive neurodegeneration of retinal ganglion cells (RGCs) and their axons, resulting in **retinal nerve fiber layer (RNFL)** attenuation, damage to the optic nerve head, and irreversible VF loss.

Since the thickness of the RNFL can effectively reflect the number of axons in nerve cells, we can estimate retinal ganglion cell survival by determining the thickness of the RNFL using **spectral-domain optical coherence tomography (SD-OCT)**.

Spectral-domain Optical Coherence Tomography

- The original OCT method, known as time-domain optical coherence tomography (TD-OCT), encoded the location of each reflection in the time information relating the position of a moving reference mirror to the location of the reflection.
- Spectral-domain optical coherence tomography (SD-OCT), instead, acquires all information in a single axial scan through the tissue simultaneously by evaluating the frequency spectrum of the interference between the reflected light and a stationary reference mirror. This method enables much faster acquisition times, resulting in a large increase in the amount of data that can be obtained during a given scan duration using SD-OCT.

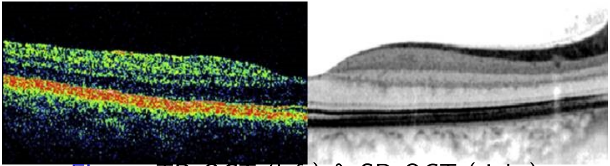
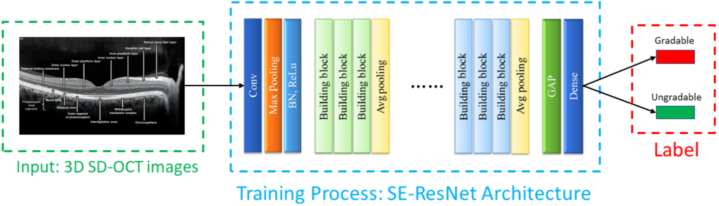


Figure: TD-OCT (left) & SD-OCT (right)

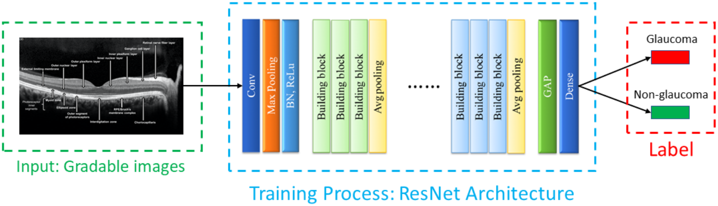
Glaucoma Diagnosis with SD-OCT Images

Two-stage process:

- Step 1: Filter out ungradable images (e.g. off-centeration, signal loss, blurriness).



- Step 2: Glaucoma diagnosis with gradable SD-OCT images.

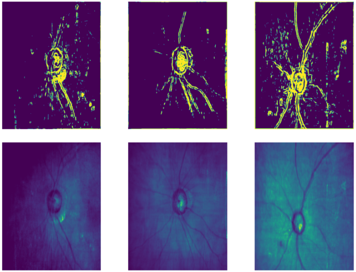


Spatial method with 2D OCT

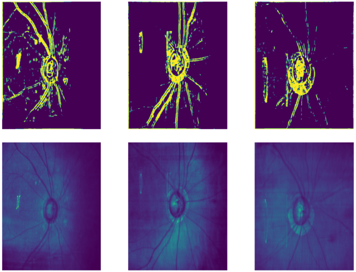
Label	mild (PACG 137) 16/10/2015	moderate (PACG 148) 29/02/2016	severe (PACG 387) 09/11/2016	mild (PACG 108) 26/05/2016	moderate (PACG 104) 02/10/2015	severe (PACG 113) 24/10/2016
Infor	-4.681	-10.2	-24.4	-3.232	-9.93	-20.3

Spatial

Original

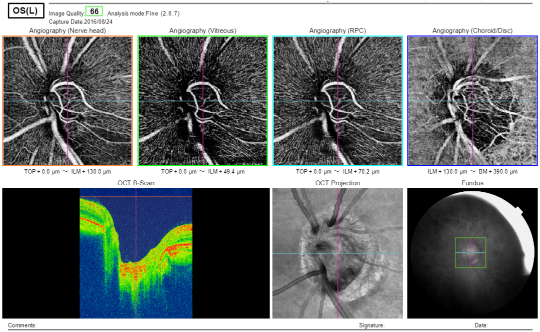


(a) OS



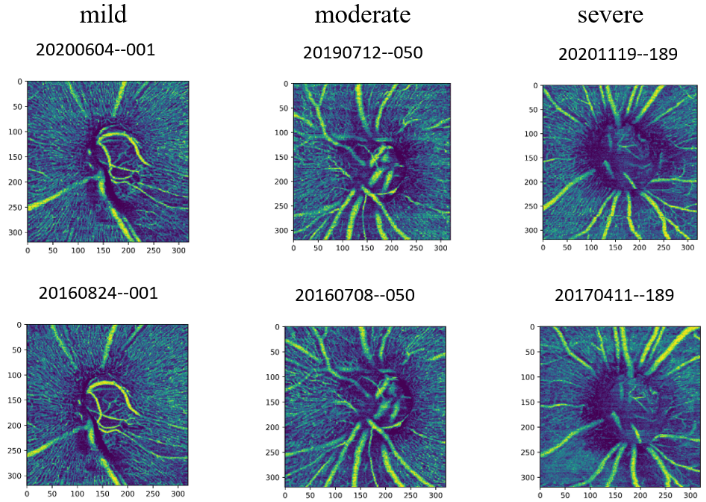
(b) OD

OCTA

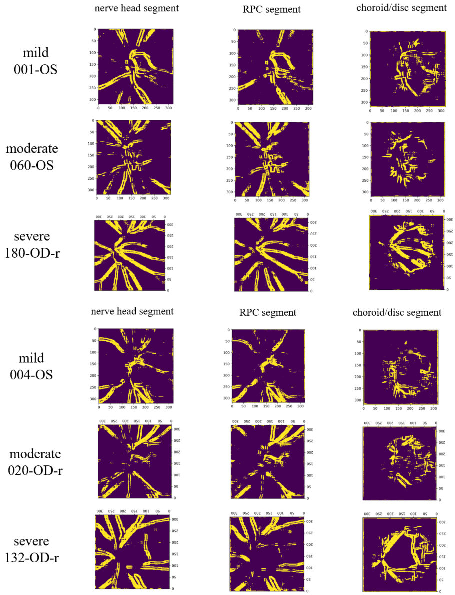


- The nerve Head segment, which is bounded by the top of the highest retinal structure and a lower segmentation line 130 μm beneath the internal limiting membrane (ILM). This visualizes the entire optic nerve head (ONH) with rim.
- The vitreous segment, which is bounded by the top segmentation line and a lower segmentation line 49.4 mμ beneath the ILM. This visualization can be used to show neovascularization of the disc (NVD) breaking into the epi-retinal space in patients with proliferative diabetic retinopathy (PDRP).
- The radial peripapillary capillary network (RPC) segment, which is bounded by the top segmentation and a lower segmentation line that is placed 70.2 mμ below the ILM. This is used to visualize the RPC surrounding the ONH, and can be an important indicator of the health of the optic nerve head in glaucoma, as well as in vascular diseases.
- The choroid/ disc segment, which is bounded by an upper segmentation line placed 130 mμ beneath the ILM and a lower segmentation line placed 390 mμ beneath the BM in order to visualize the entire depth of the disc.
- The OCT B-Scan.
- The OCT projection.
- The fundus image and the location of the scan.

RPC segment


mild
moderate
severe
20200604--001
20190712--050
20201119--189
20160824--001
20160708--050
20170411--189

Spatial method with OCTA



The End