

CU-Net: Towards continuous multi-class contour detection for retinal layer segmentation in OCT images

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Concepts

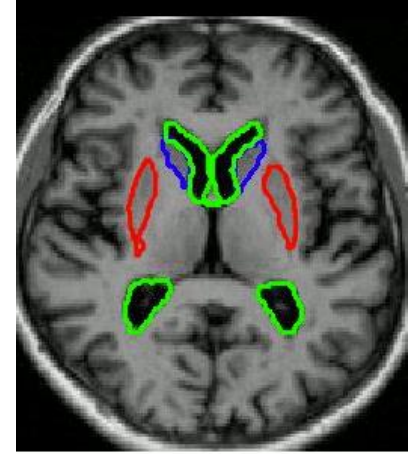
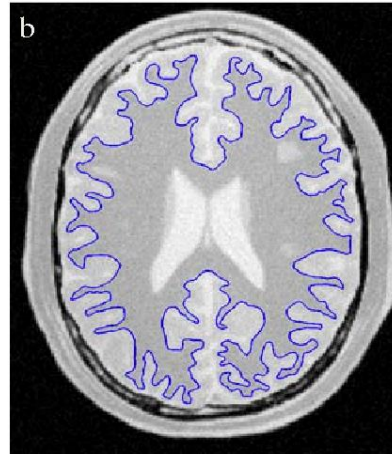
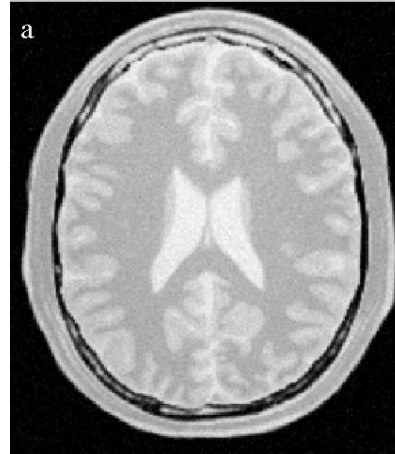
1. Contour detection
2. Optical Coherence Tomography (OCT)
3. Retinal layer segmentation (RLS)

Contour detection

- Medical image segmentation



(i) Contour detection on lung CT scans



(ii) Contour detection on brain MRI

Contour detection

- Object detection and scene understanding



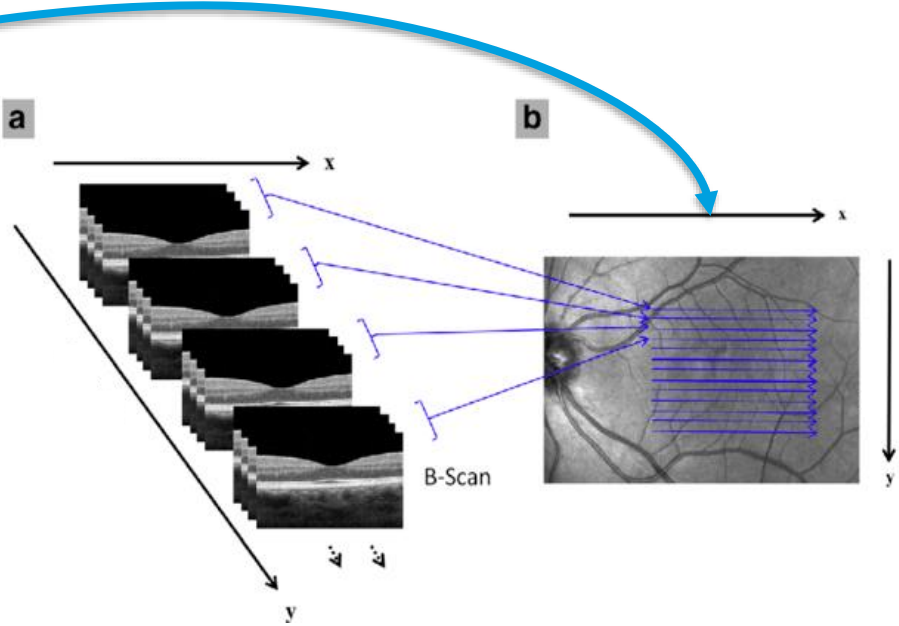
OCT images

- Retinal imaging procedure
- Exposes retinal cross-sections
- Retinal disease diagnosis
 - Diabetic Macular Edema (DME)
 - Sickle-cell Retinopathy (SCR)
 - Multiple Sclerosis (MS)

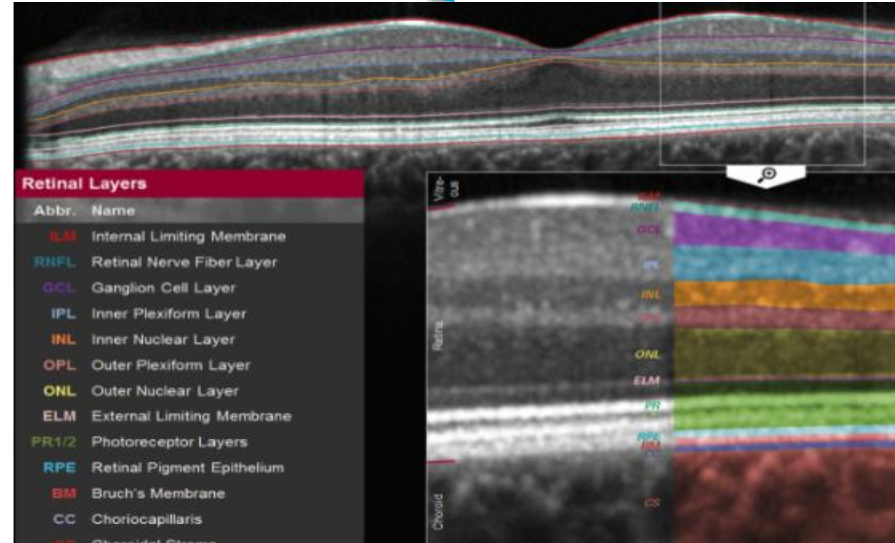
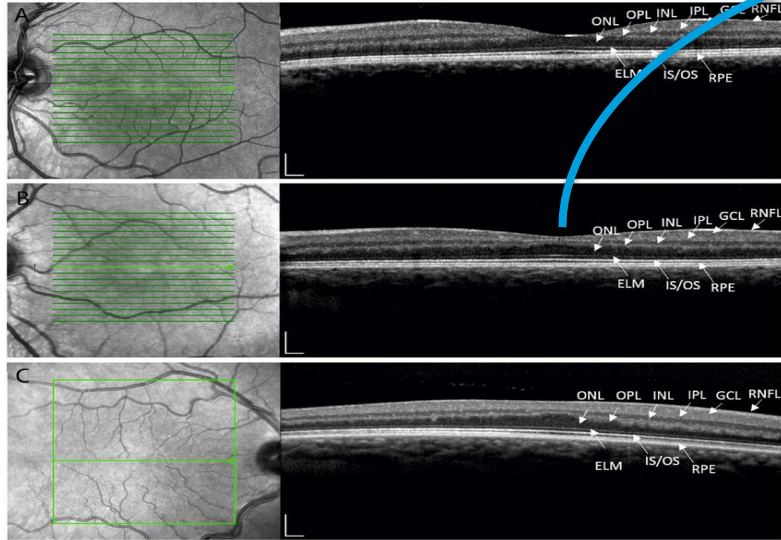


SPECTRALIS OCT – Heidelberg Engineering

OCT images



Retinal layer segmentation (RLS) from OCT images



Properties of a reliable RLS system

- Accurately approximate retinal contours
- Detect contours in the correct hierarchical order
- Produce thin, crisp, and unambiguous contours
- Produce continuous contours along the vertical axis

Existing work

- Contour detection
- Retinal layer segmentation

Existing literature (contour detection)

Li et al.

- Edge track
- Active contour tracking system
- Human tongue ultrasound

Kang et al.

- Fast contour extraction model based on Multiple Cue Inhibition operator name SpeedMCI.

Ronneberger et al.

- UNET
- Encoder-decoder architecture
- Medical image segmentation

Wang et al.

- SDUNet
- Variation of UNET
- Dilated convolution

Yang et al.

- Fully convolutional encoder-decoder network
- Multi-scale edge supervision

Deng et al.

- CNN to produce sharp boundaries
- Weighted cross entropy and dice coefficient loss (Novel at the time)

Existing literature (Retinal layer segmentation)

S. Xiao et al. (2010)

- Graph theory
- Weighted graphs from gradients

Tian et al. (2015)

- Shortest-path based graph search
- Inter-frame similarities to refine search regions

Chiu et al. (2015)

- 7-layer segmentation of DME
- Duke dataset
- Graph theory, kernel regression

Giovinco et al. (2015)

- Gradient approx.
- Total variation denoising, shock filter, gradients, region fusion

Sun et al. (2017)

- Gradient approx. directly to OCT volumes

Devalla et al. (2018)

- DRUNET
- Custom U-net
- Segment 6 tissue layers

He et al. (2019)

- Op 1: pixelwise label
- Op 2: surface maps
- Duke and JHU

Li et al. (2020)

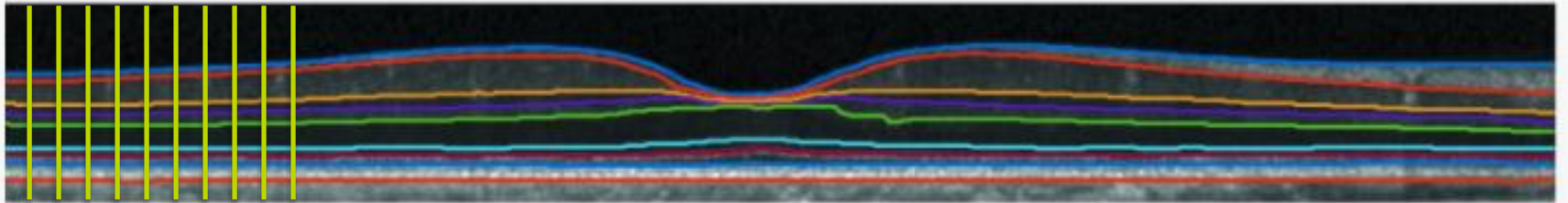
- DeepRetina
- X-65, enc-dec
- Layer thickness

Hsia et al. (2021)

- Mask RCNN
- Choroidal thickness

Current state of the art: Works by He et al.

- Topology guarantee module
 - ❖ $s_j(i)^{new} = s_{j-1}(i) + \text{ReLU}(s_j(i) - s_{j-1}(i))$
- Surface position distribution
 - ❖ Column-wise soft argmax



Our idea

- Interpret retinal contours as natural cubic spline
 - Consider continuity as an inherent property of retinal layers
 - Interpolate discrete outputs from CNN network

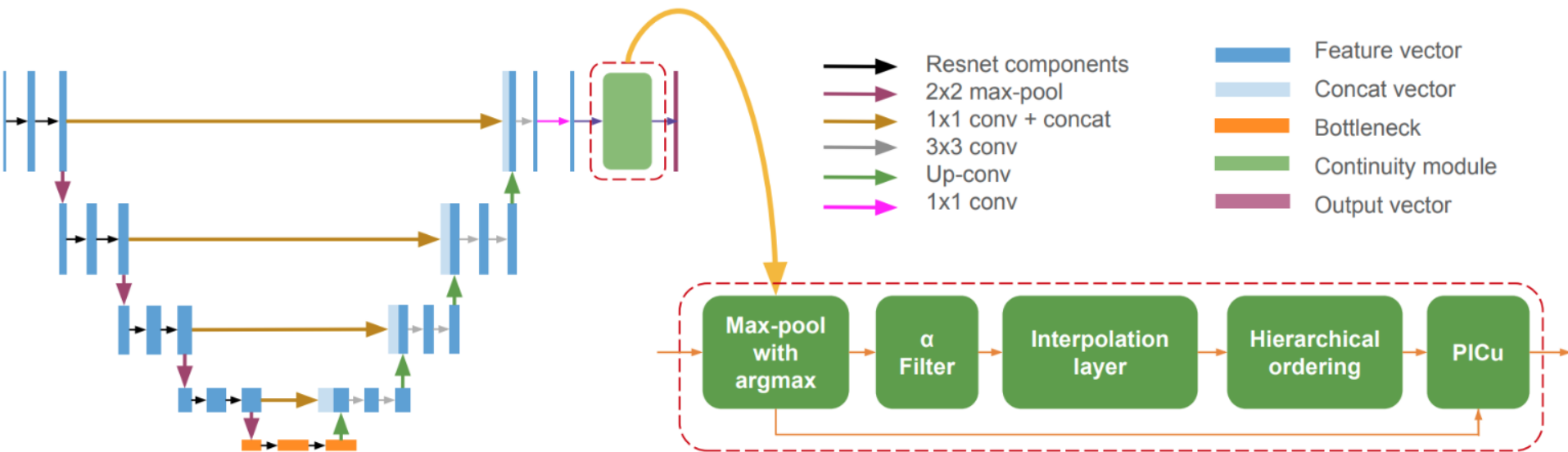


Contributions

- Continuous U-Net (CU-Net): Residual U-Net with a novel continuity module
 - Polynomial continuity unit (PICu)
- Verification on 3 OCT datasets
 - State-of-the-art results on benchmark datasets
 - Consistent over changes in retinal structures caused by multiple pathologies



CUNet



Thank you!