CU-Net: Towards Continuous Multi-class Contour Detection For Retinal Layer Segmentation in OCT Images

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BACKGROUND

- **Optical Coherence Tomography (OCT)** is an imaging procedure that takes cross-sections of a retina to diagnose retinal diseases.
- **Retinal layer segmentation (RLS)** provides retinal contours for research and diagnosis.
- A good RLS method should be **accurate, hierarchically ordered, continuous, and unambiguous.**
- **Continuous U-Net (CU-Net)** architecture contains Res-U-Net and continuity unit which produce high quality retinal contours.

RESULTS FROM CU-NET

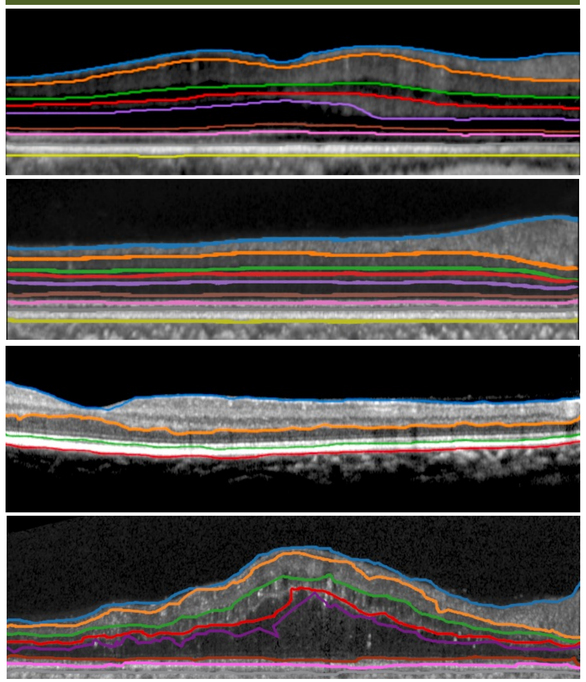
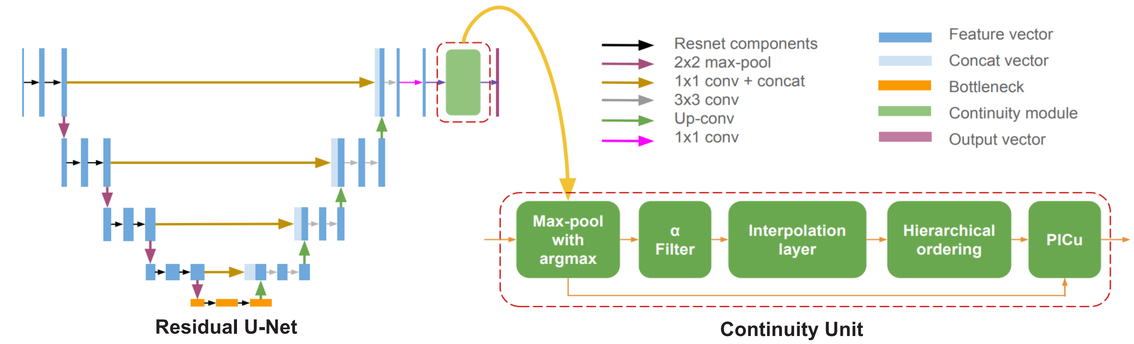


Fig 1: (Top to bottom) Contours detected by CU-Net on images from datasets: JHU-MS, JHU-HC, Nemours, and Duke

ARCHITECTURE



CONTINUITY UNIT

- **Pooling layer:** Column-wise maxpool with argmax
  - $P(V_{ij}^{c}) = (vmax_{ij}, j)$
- **Alpha filter:** High pass filter with cutoff frequency α
  - $A(P) = A(vmaxij, j) = \begin{cases} (i,j), & vmaxij < \alpha \\ (i, None), & otherwise \end{cases}$

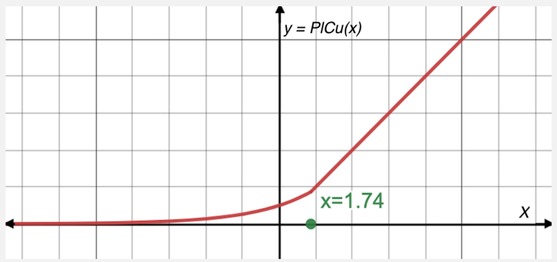


Fig 2: Polynomial Continuity Unit (PlCu)

- **Interpolation layer:** Based on natural cubic spline
  - $f(x) = g_0 + g_1x + g_2x^2 + g_3x^3$
- **Hierarchical ordering:**
  - $j_i^{c+1} = max\{j_i^{c}, j_i^{c+1}\}$
- **Polynomial Continuity Unit (PlCu):**
  - $PlCu(x) = \begin{cases} e^{\frac{x}{\pi}}, & if\ x \le \beta \\ x, & otherwise \end{cases}$
  - $PlCu'(x) = \begin{cases} e^{\frac{x}{\pi^2}}, & if\ x < \beta \\ 1, & if\ x > \beta \\ undefined, & if\ x = \beta \end{cases}$

Where, β=1.74 is a threshold where $e^{\frac{x}{\pi}} = x$

CU-NET PRODUCES ACCURATE, UNAMBIGUOUS, HIERARCHICALLY ORDERED, AND CONTINUOUS RETINAL LAYER CONTOURS IN OCT IMAGES.

TO KNOW MORE ABOUT OUR WORK, PLEASE SCAN THE QR CODE:

Dataset

Chiu et al. (Duke)	110 OCT, 10 people with DME
He et al. (JHU)	1715 OCT, 14 healthy and 21 people with MS
Nemours	2205 OCT, 45 children with SCR

Duke data: MAD, std deviation (μm)

L	Chiu et al.	Karri et al.	Rathke et al.	He et al.	Ours
1	6.59	4.47	4.66	4.51	**2.51** (1.48)
2	8.38	11.77	6.78	6.71	**5.04** (2.77)
3	9.04	11.12	8.87	**8.29**	8.47 (3.78)
4	11.02	17.54	11.02	**10.71**	10.84 (2.95)
5	11.01	16.74	13.60	**9.88**	11.82 (2.29)
6	4.84	4.99	4.61	**4.41**	4.42 (1.06)
7	5.74	5.35	7.06	4.52	**4.47** (0.73)
8	5.91	**4.30**	5.11	4.61	4.32 (1.27)
avg	7.82	9.54	7.71	6.70	**6.48** (2.04)

JHU Data: MAD, std deviation (μm)

L	Aura	R-Net	RelayNet	He et al.	Ours
1	2.37 (0.69)	2.38 (1.22)	3.17 (1.08)	2.41 (0.81)	**2.23** (1.27)
2	3.09 (1.22)	3.10 (1.29)	3.75 (1.59)	2.96 (1.70)	**2.06** (1.09)
3	3.43 (1.02)	2.89 (0.90)	3.42 (0.90)	2.87 (1.69)	**1.98** (0.85)
4	3.25 (0.95)	3.15 (0.98)	3.65 (0.92)	3.19 (1.49)	**2.24** (0.88)
5	2.96 (1.29)	2.76 (1.26)	3.28 (1.33)	2.72 (1.70)	**2.67** (1.07)
6	2.69 (0.84)	2.65 (1.05)	3.04 (0.86)	2.65 (1.14)	**1.69** (0.55)
7	2.07 (0.96)	2.10 (1.03)	2.73 (0.71)	2.01 (0.88)	**1.73** (0.83)
8	3.77 (1.71)	3.81 (1.89)	4.22 (2.06)	3.55 (1.73)	**1.51** (0.76)
9	2.89 (2.37)	3.71 (2.47)	3.09 (1.62)	3.10 (2.21)	**1.59** (0.67)
avg	2.95 (1.23)	2.95 (1.34)	3.37 (1.23)	2.83 (1.48)	**1.57** (0.89)

CONCLUSIONS

- Met all requirements for a reliable RLS system
- Lowest MAD achieved in benchmark datasets
- Future research in volumetric OCT analysis and parameter sharing between cross-sections

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