Partial Vessels Annotation-based Coronary Artery Segmentation with Self-training and Prototype Learning

Zheng Zhang[1], Xiaolei Zhang[2], Yaolei Qi[1], Guanyu Yang[1,3,4*]

1.Key Laboratory of New Generation Artificial Intelligence Technology and Its Interdisciplinary Applications (Southeast University), Ministry of Education, Nanjing, China

2.Dept. of Diagnostic Radiology, Jinling Hospital, Medical School of Nanjing University, Nanjing, China

3.Jiangsu Provincial Joint International Research Laboratory of Medical Information Processing, Southeast University, Nanjing, China

4.Centre de Recherche en Information Biomédicale sino-français (CRIBs), Strasbourg, France

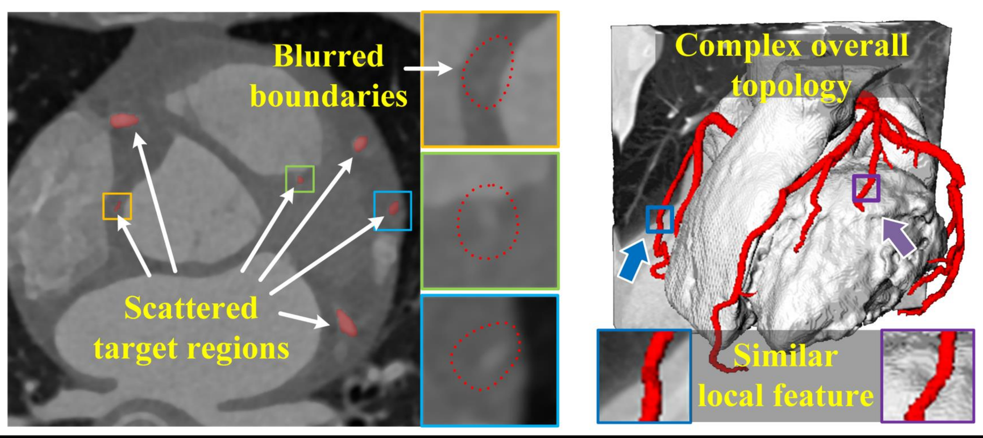
Motivation

1. Difficult labeling on 3D CCTA images

The scattered target regions as well as the blurred Boundaries make the annotating process time-consuming.

2. Complex topology and similar local feature

Coronary artery shows complex and slender structures but similar feature in a local perspective.



Proposed Annotation

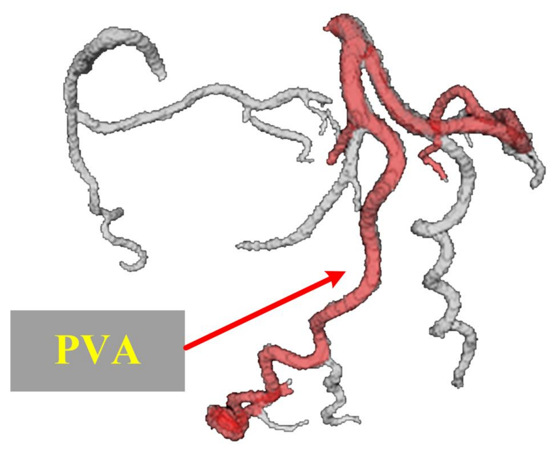
What is Partial Vessels Annotation (PVA) ?

PVA is a special form of partial annotation (PA), under which only a limited part of target regions are labeled. PVA labels vessels continuously from the proximal end to the distal end, while the labeled regions of PA are typically randomly selected.

What are the merits of PVA?

1. PVA balances efficiency and informativity. PVA only requires clinicians to label vessels within restricted regions in adjacent slices.

2. PVA provides flexibility. PVA allows clinicians to focus their labeling efforts on vessels of particular interest.

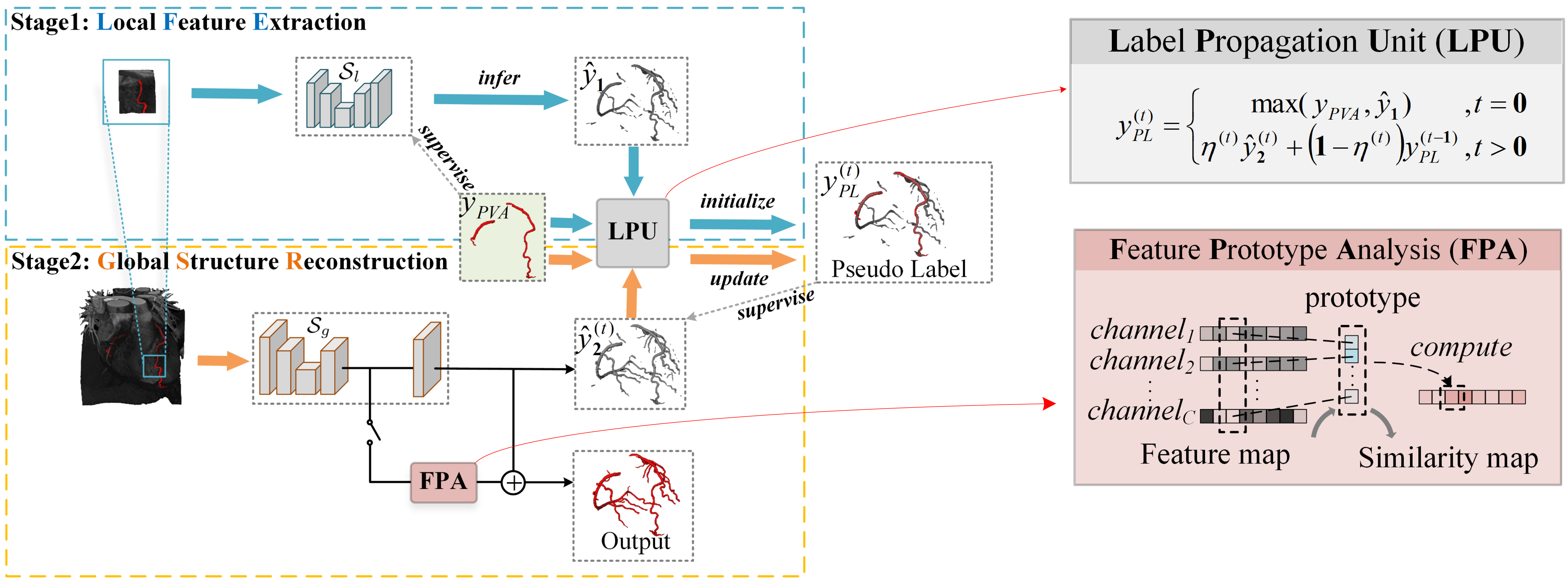


Proposed Framework for Coronary Artery Segmentation under PVA

The framework works in two stages.

1. LFE stage extracts the local features of coronary artery , and then propagates the knowledge to unlabeled regions.

2.GSR stage leverages prediction consistency to correct the errors during the iterative self-training process.

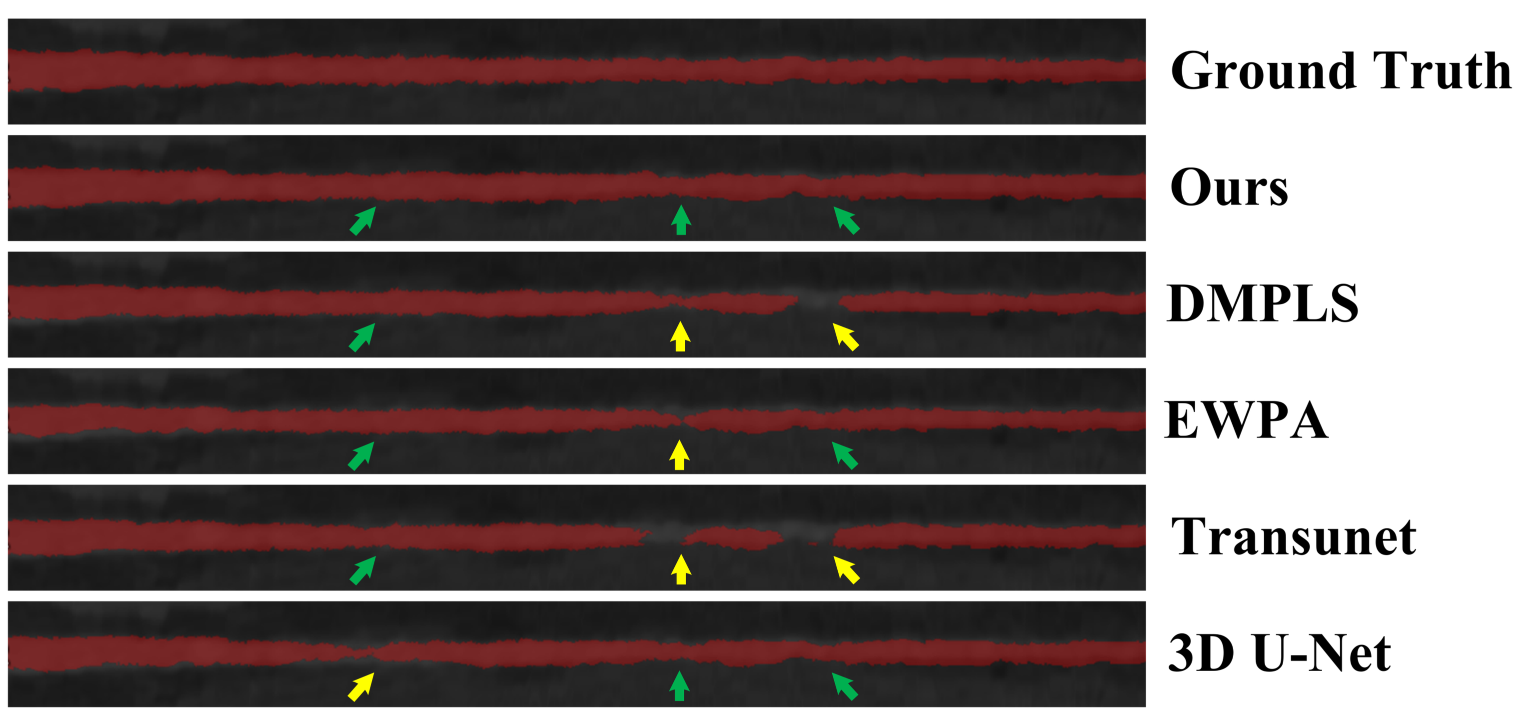


Results

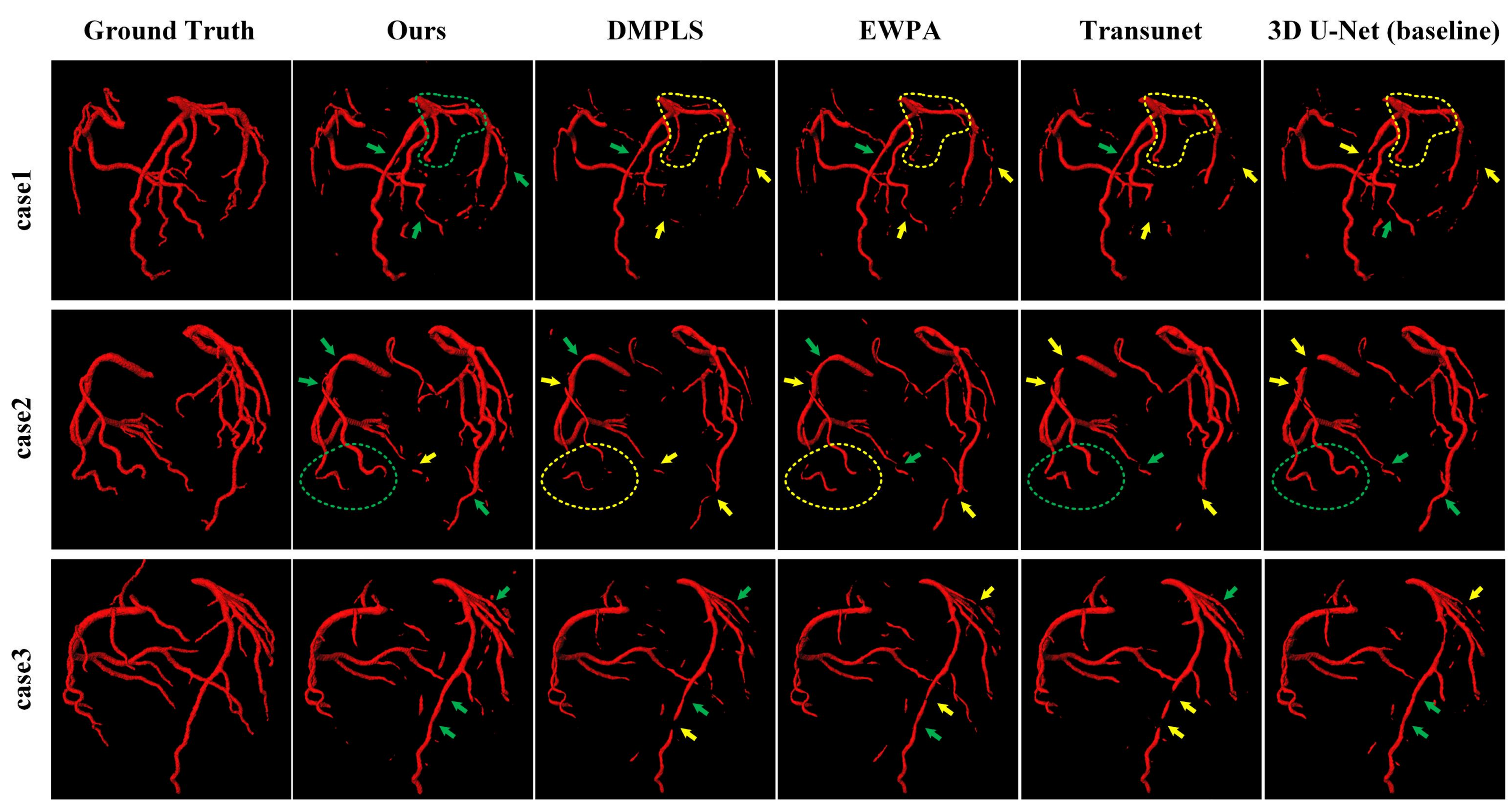
Result 1: Our proposed framework outperforms the competing methods under PVA (24.29% vessels labeled), the performance which is comparable to that of the baseline model using full annotation (F A , 100% vessels labeled).

Label	Method	Dice(%)↑	RDice(%)↑	OV(%)↑	OF↑		
					LAD	LCX	RCA
PVA	3D U-Net [3]	$60.60_{\pm 7.09}$	$69.45_{\pm 7.82}$	$62.24_{\pm 6.43}$	$0.647_{\pm 0.335}$	$0.752_{\pm 0.266}$	$0.747_{\pm 0.360}$
	HRNet [17]	$48.72_{\pm 7.16}$	$52.31_{\pm 7.96}$	$37.81_{\pm 6.61}$	$0.490_{\pm 0.297}$	$0.672_{\pm 0.301}$	$0.717_{\pm 0.356}$
	Transunet [1]	$63.08_{\pm 6.42}$	$71.97_{\pm 7.38}$	$61.21_{\pm 6.40}$	$0.669_{\pm 0.274}$	$0.762_{\pm 0.243}$	$0.728_{\pm 0.362}$
	EWPA [12]	$55.41_{\pm 6.15}$	$61.54_{\pm 6.83}$	$60.48_{\pm 5.17}$	$0.659_{\pm 0.334}$	$0.759_{\pm 0.286}$	$0.749_{\pm 0.364}$
	DMPLS [10]	$59.12_{\pm 7.69}$	$65.81_{\pm 8.15}$	$59.99_{\pm 5.80}$	$0.711_{\pm 0.292}$	$0.775_{\pm 0.284}$	$0.711_{\pm 0.358}$
	Ours	$\mathbf{71.45}_{\pm 6.07}$	$\mathbf{83.14}_{\pm 6.72}$	$\mathbf{75.40}_{\pm 6.15}$	$\mathbf{0.895}_{\pm 0.226}$	$\mathbf{0.915}_{\pm 0.190}$	$\mathbf{0.879}_{\pm 0.274}$
FA	3D U-Net	$83.14_{\pm 3.52}$	$90.91_{\pm 4.18}$	$89.00_{\pm 4.75}$	$0.913_{\pm 0.231}$	$0.843_{\pm 0.301}$	$0.873_{\pm 0.265}$

Visualization 1: Comparison on MPR



Visualization 2: Comparison of the segmentation results under PVA



Result 2: Different components are effective in our proposed method.

S_l	LPU		S_g	FPA	Dice(%)↑	RDice(%)↑	OV(%)↑	OF↑		
	PLI	PLU						LAD	LCX	RCA
✓					$60.60_{\pm 7.09}$	$69.45_{\pm 7.82}$	$62.24_{\pm 6.43}$	$0.647_{\pm 0.335}$	$0.752_{\pm 0.266}$	$0.747_{\pm 0.360}$
✓	✓		✓		$64.23_{\pm 6.44}$	$73.81_{\pm 6.89}$	$66.19_{\pm 5.63}$	$0.751_{\pm 0.328}$	$0.813_{\pm 0.231}$	$0.784_{\pm 0.349}$
✓	✓	✓	✓		$71.43_{\pm 7.20}$	$81.70_{\pm 6.92}$	$72.13_{\pm 5.94}$	$0.873_{\pm 0.227}$	$0.860_{\pm 0.223}$	$0.808_{\pm 0.334}$
✓	✓	✓	✓	✓	$\mathbf{71.45}_{\pm 6.07}$	$\mathbf{83.14}_{\pm 6.72}$	$\mathbf{75.40}_{\pm 6.15}$	$\mathbf{0.895}_{\pm 0.226}$	$\mathbf{0.915}_{\pm 0.190}$	$\mathbf{0.879}_{\pm 0.274}$

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