Semi-supervised Segmentation of Histopathology Images with Noise-Aware Topological Consistency

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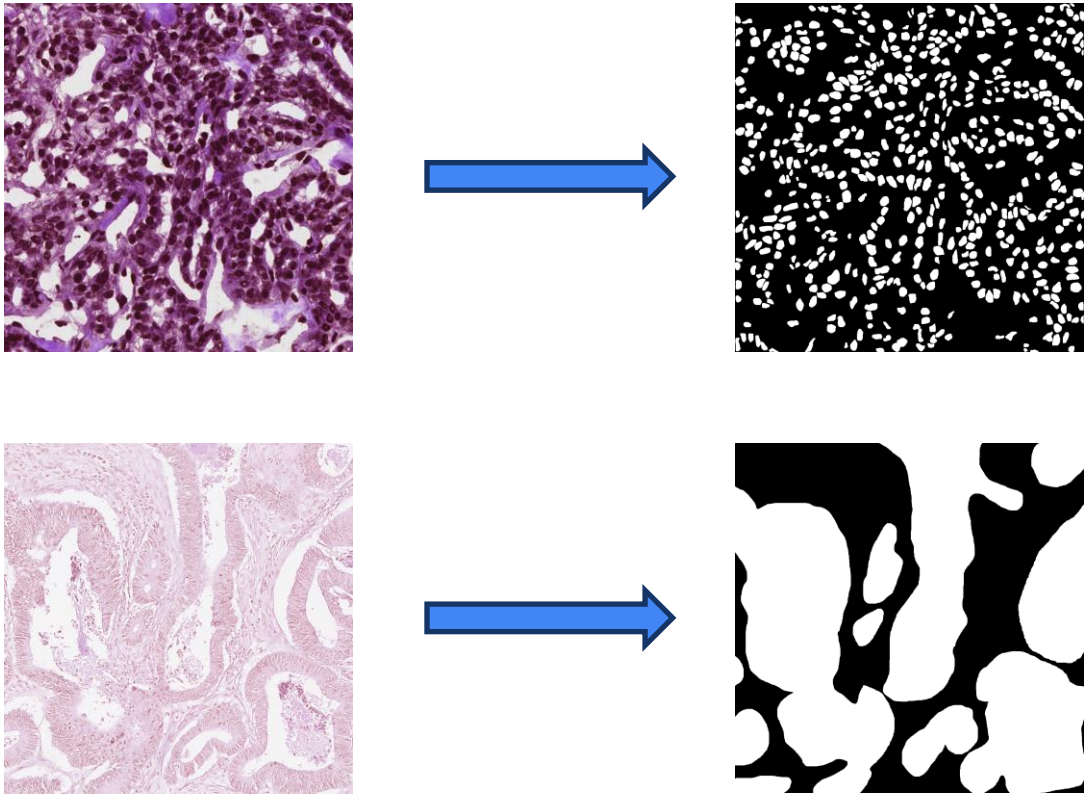
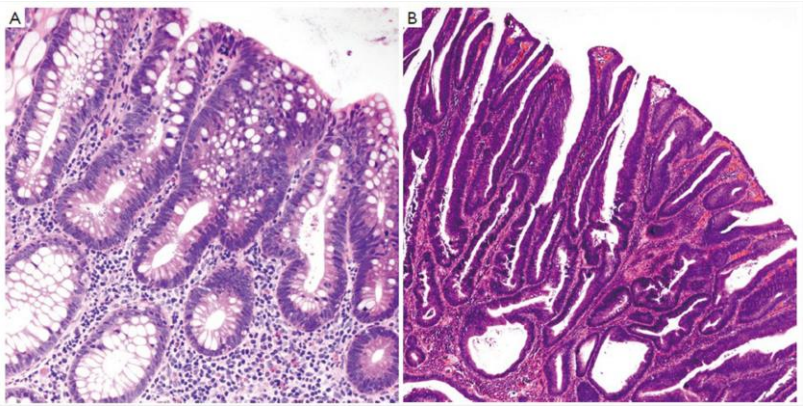
Gland/Nuclei Segmentation in Digital Pathology



Importance

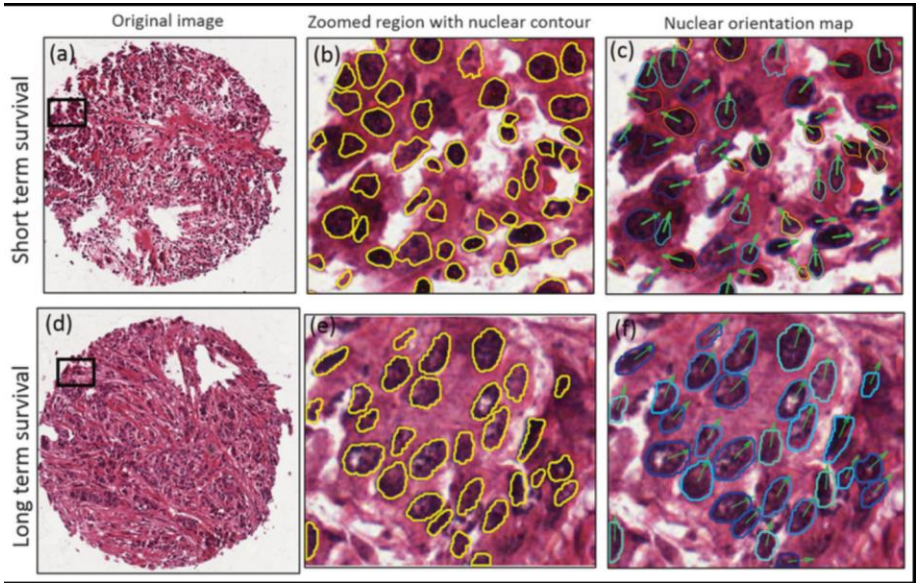
Downstream analysis

- e.g.: Basis of diagnosis, survival prediction



Tubular adenoma
(Lower risk to colon cancer)

Tubulovillous adenoma
(Higher risk to colon cancer)

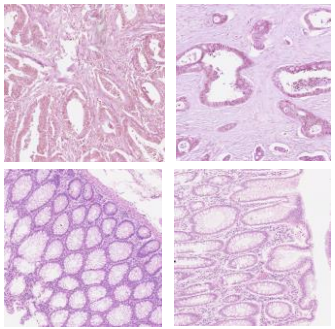


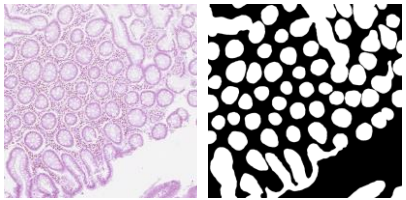
[1] Fleming, Matthew, et al. "Colorectal carcinoma: Pathologic aspects." *Journal of Gastrointestinal Oncology* 3.3 (2012): 153.
[2] Lu, Cheng, et al. "Nuclear shape and orientation features from H&E images predict survival in early-stage estrogen receptor-positive breast cancers." *Laboratory investigation* 98.11 (2018): 1438-1448.

The Problem

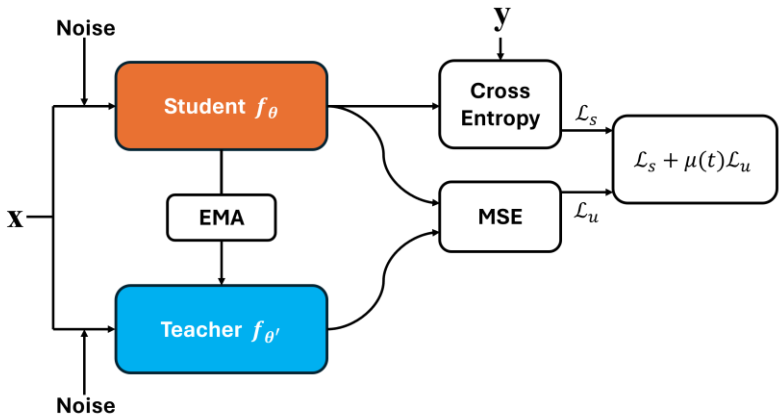
- Limited availability of labeled histopathology data
  - Heavy annotation burden
  - Needs domain expertise
- Semi-supervised methods
  - Small group of labeled data + large group of unlabeled data
  - Consistency-based regularization methods:
    - Enforce consistent predictions under data augmentation.
  - Mean-Teacher Framework

Unlabeled Data





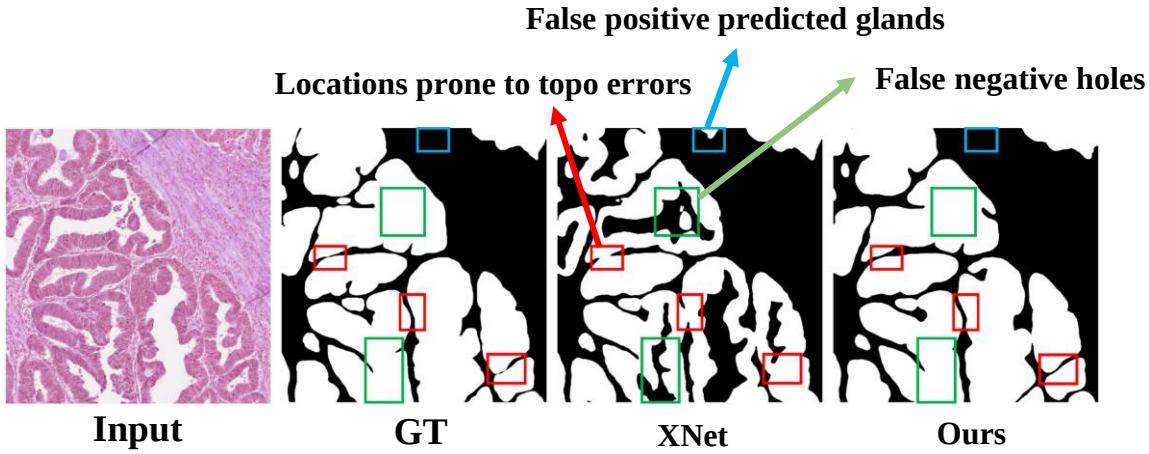
Labeled Data



Issues in current methods

- Consistency-based semi-supervised methods
  - Focus on per pixel/voxel consistency
  - Fail to learn the topological characteristics from the unlabeled data
  - Cannot fix the structural errors, such as wrongly merging glands/nuclei

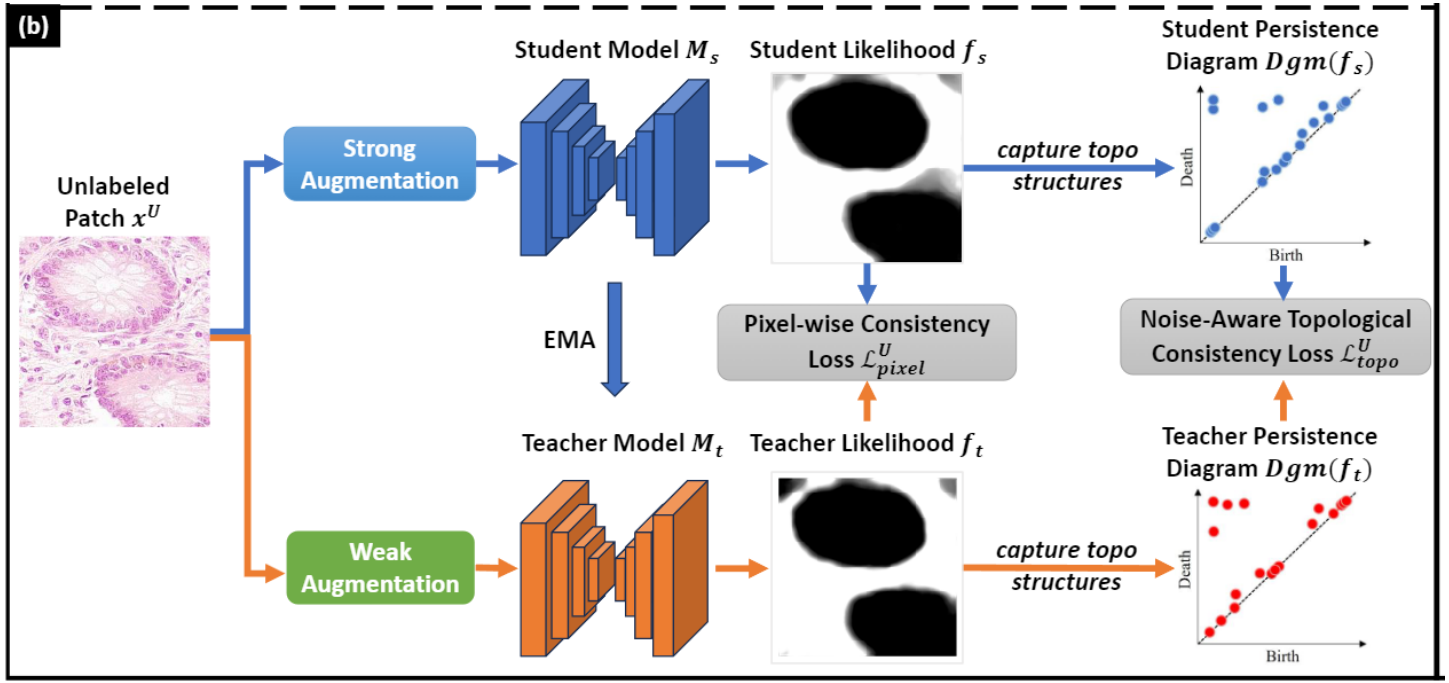
- Existing methods
  - XNet[1], URPC[2]



[1] Zhou, Yanfeng, et al. "Xnet: Wavelet-based low and high frequency fusion networks for fully-and semi-supervised semantic segmentation of biomedical images." *Proceedings of the IEEE/CVF International Conference on Computer Vision*. 2023.
[2] Luo, Xiangde, et al. "Semi-supervised medical image segmentation via uncertainty rectified pyramid consistency." *Medical Image Analysis* 80 (2022): 102517.

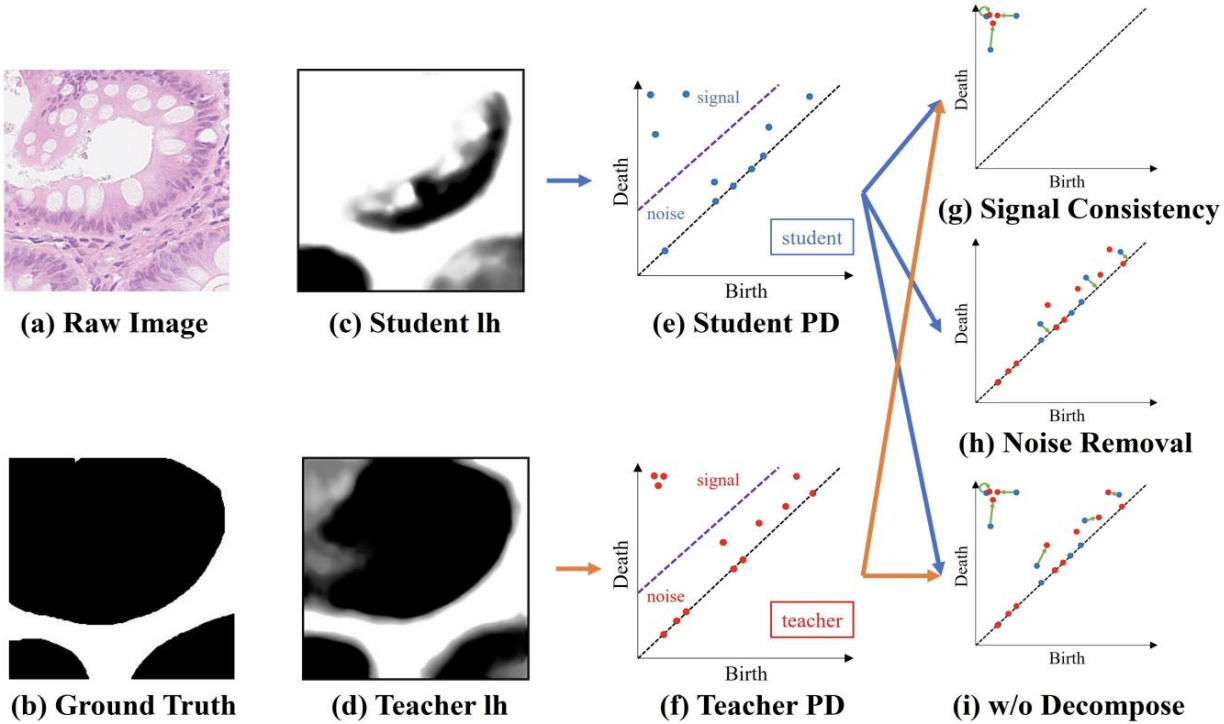
Our Approach

- Under different perturbations, the topology of the outputs should be consistent.
- Enforce the topological consistency between noisy topological features.



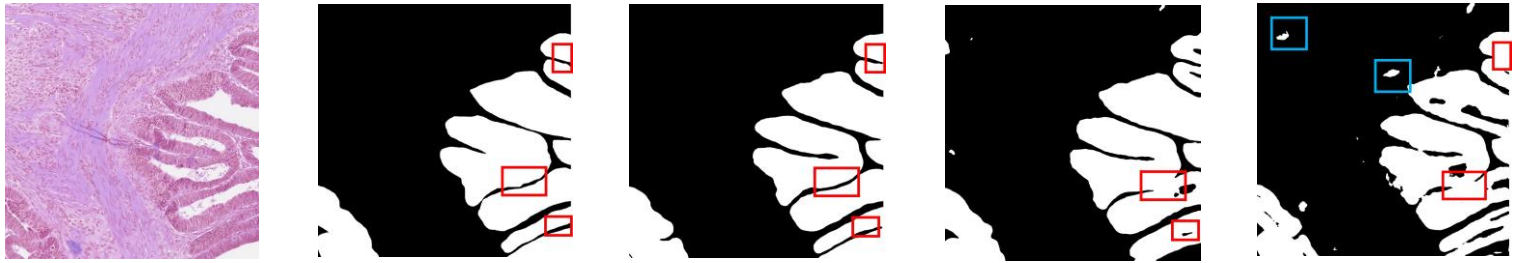
Contributions

- Decomposition strategy to avoid directly matching between noisy structures
- Learn robust topological representations from the unlabeled data
- Backbone agnostic and stable to small perturbations



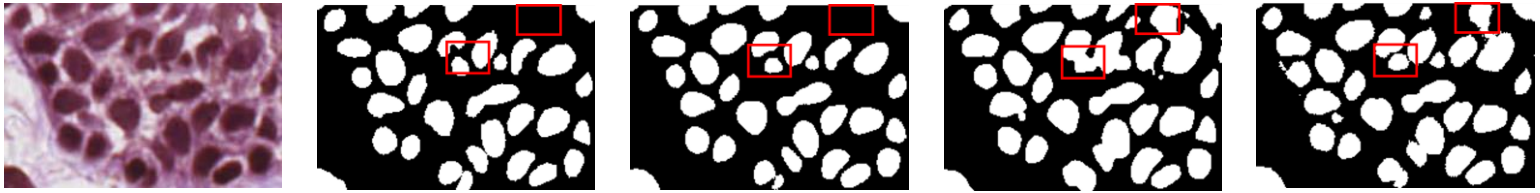
Qualitative Results

Glands



Input GT Ours URPC XNet

Nuclei



Input GT Ours URPC XNet

Quantitative Results

		Pixel-Wise	Topology-Wise		
Dataset	**Method**	**Dice_obj ↑**	**Betti Error ↓**	**BME ↓**	**VOI ↓**
CRAG (20%)	URPC	0.849	2.489	99.500	0.912
	XNet	0.883	0.422	10.900	0.735
	Ours	**0.898**	**0.226**	**8.575**	**0.709**
MoNuSeg (20%)	URPC	0.779	7.977	207.857	0.832
	XNet	0.776	6.750	198.525	0.831
	Ours	**0.793**	**4.250**	**188.642**	**0.787**

Conclusion & Thank you

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Code:
https://github.com/Melon-Xu/TopoSemiSeg
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