Topology Aware Fully Convolutional Networks for Histology Gland Segmentation

SFU SIMON FRASER UNIVERSITY ENGAGING THE WORLD

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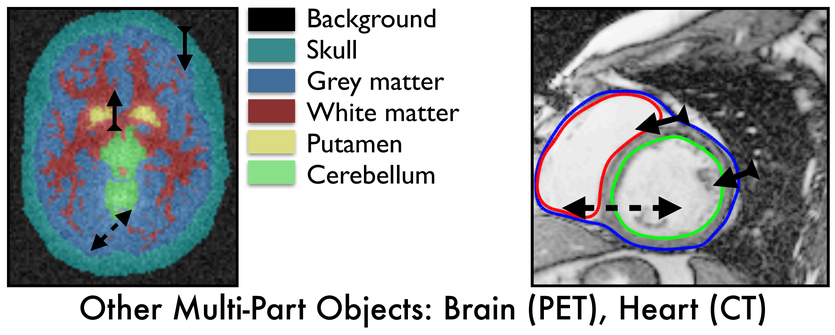
Multi-Part Object Segmentation

A ⟶ Contains ⟶ B A ⇠ Excludes ⇢ B

Colon Adenocarcinoma (Warwick-QU dataset) [1]



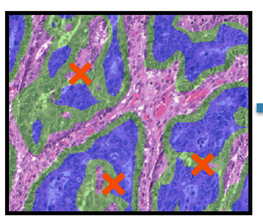
Other Multi-Part Objects: Brain (PET), Heart (CT)

Traditional Segmentation Methods: level sets, graph cuts

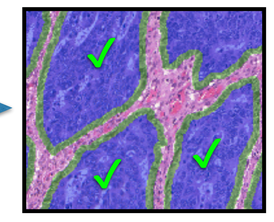
- ✓ Flexible priors encoded as energy terms
- ✗ Sensitive to data terms and initialization

Deep Learning: fully convolutional networks

- ✗ Pixel-wise only loss (energy)
- ✓ Strong and robust data representation

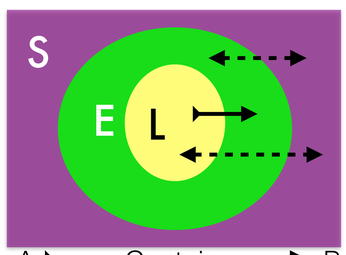


Proposed: prior-augmented loss in fully convolutional networks



Proposed Topology-Augmented Loss

Multi-Region Interactions



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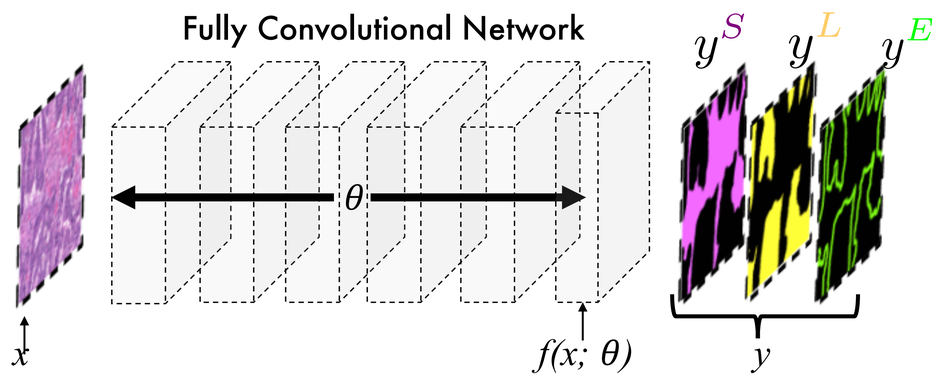
A ⇠ Excludes ⇢ B

Topological Validity Indicator

S	0	1	0	1	0	1	0	1
E	0	0	1	1	0	0	1	1
L	0	0	0	0	1	1	1	1
$V(y_p)$	0	1	1	0	0	0	1	0
y_p	-	S	E	-	-	-	L	-

V = 1 valid V = 0 invalid

Fully Convolutional Network



$$\theta^* = \arg\min_\theta \sum_{n=1}^{N} \alpha_1 \mathcal{L}_T(x;\theta) + \alpha_2 \mathcal{L}_S(x;\theta)$$

Pixel-Wise Topology Loss: favours topologically-valid label assignments

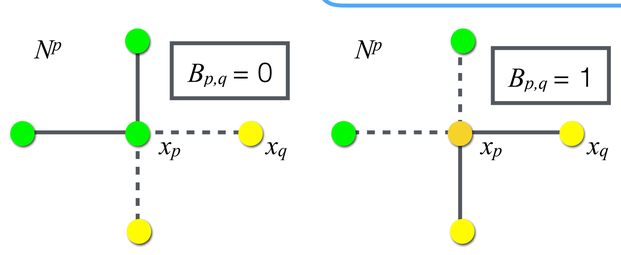
Pairwise Regularizer: favours smooth segmentations

$$\mathcal{L}_T(x;\theta) = \sum_{p\in\Omega} \sum_{r\in\{L,S,E\}} -y_p^r \log P(y_p^r = 1|x_p;\theta)$$

Marginalized probability

$$P(y_p|x_p;\theta) = \frac{1}{Z} \prod_r e^{f_r(x_p;\theta) y_p^r} \times V(y_p) \quad \forall y_p \in \{0,1\}^R \quad Z = \sum_{y_p} P(y_p|x_p;\theta)$$

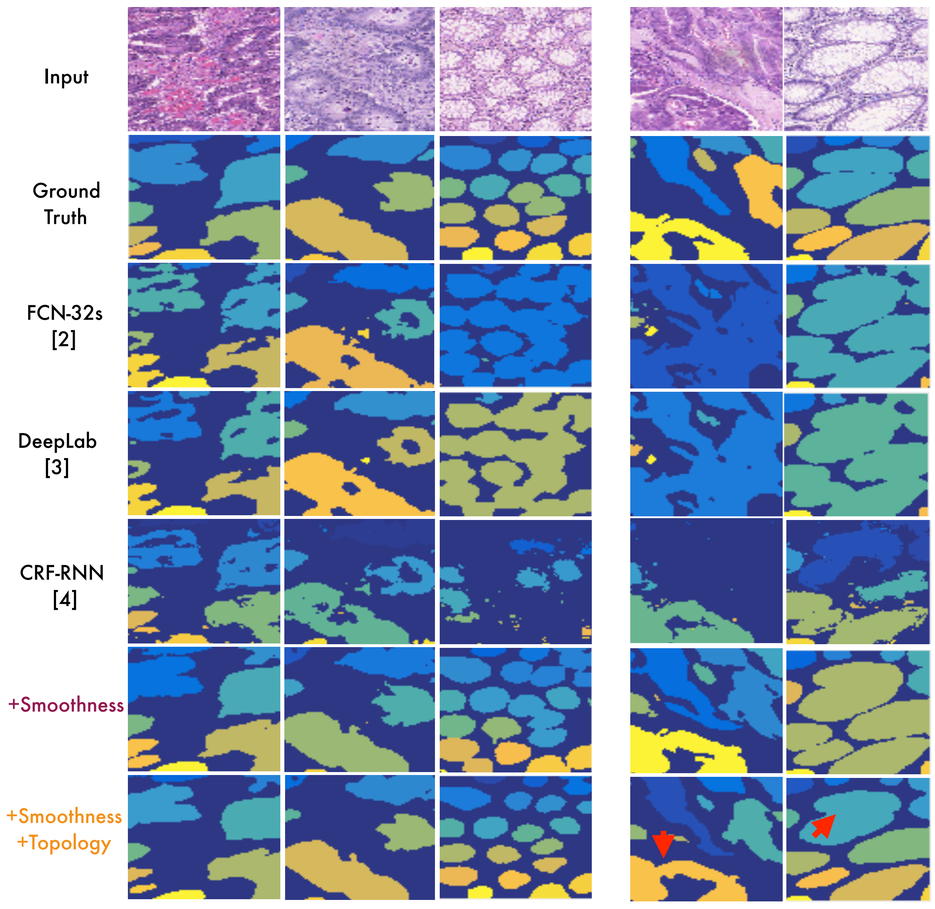
Predicted joint probability · Validity indicator · All possible label vectors · Partition function

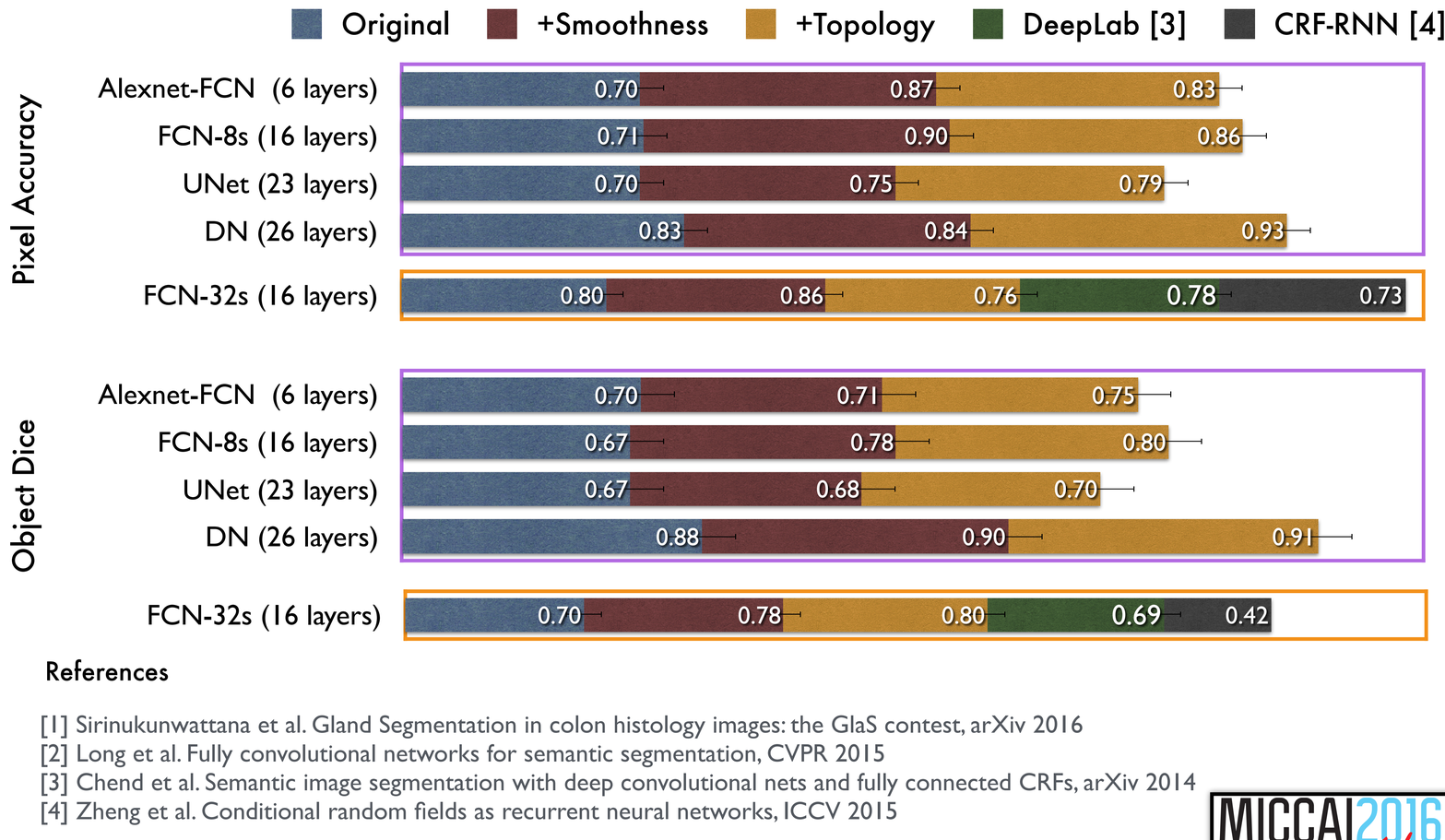


$$\mathcal{L}_S(x;\theta) = \sum_p \sum_r \sum_{q\in\mathcal{N}^p} B_p^q \times y_p^r \times |P(y_p^r|x_p;\theta) - P(y_q^r|x_q;\theta)|$$

Experimental Performance Evaluation

Dataset	Experiment 1	Experiment 2
MICCAI'15 GLaS Challenge [1] 70 Training / 15 Validation / 80 Test	Proposed method vs. various architectures	Proposed method vs. graphical models
Proposed method vs. challenge winner +3% Dice, +18% F1 score , -12% Hausdorff	+10 to 15% pixel accuracy +3 to 5% Dice	-2 to +3% pixel accuracy +13 to 38% Dice





References

[1] Sirinukunwattana et al. Gland Segmentation in colon histology images: the GlaS contest, arXiv 2016
[2] Long et al. Fully convolutional networks for semantic segmentation, CVPR 2015
[3] Chend et al. Semantic image segmentation with deep convolutional nets and fully connected CRFs, arXiv 2014
[4] Zheng et al. Conditional random fields as recurrent neural networks, ICCV 2015

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