Boundary Losses in Segmentation problems

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ODS Pet Projects

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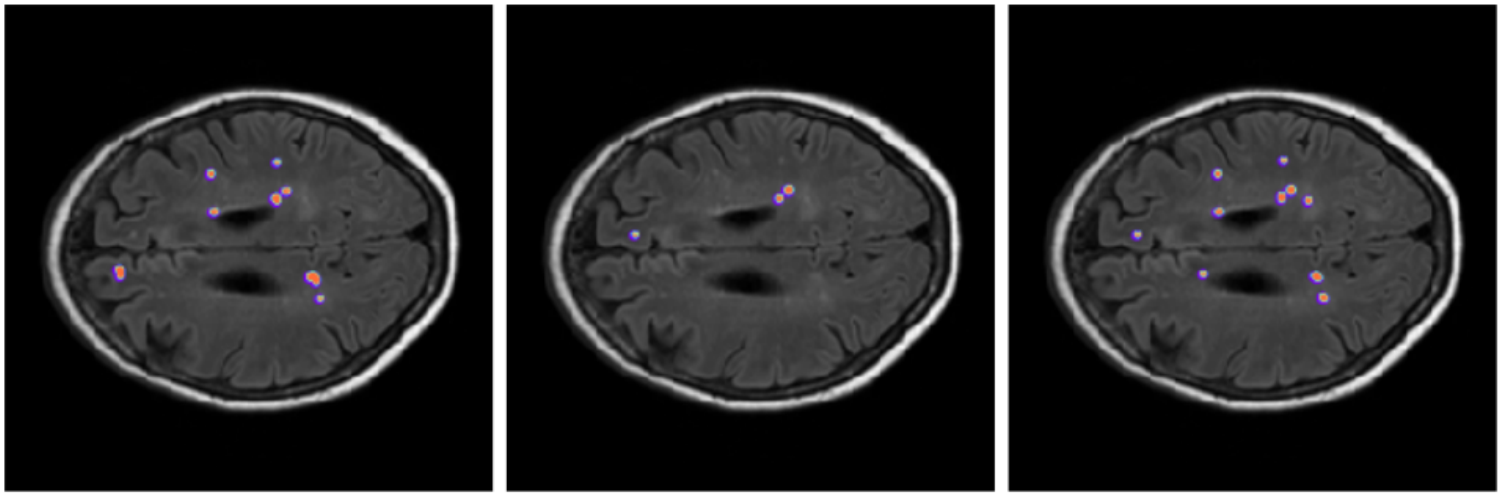
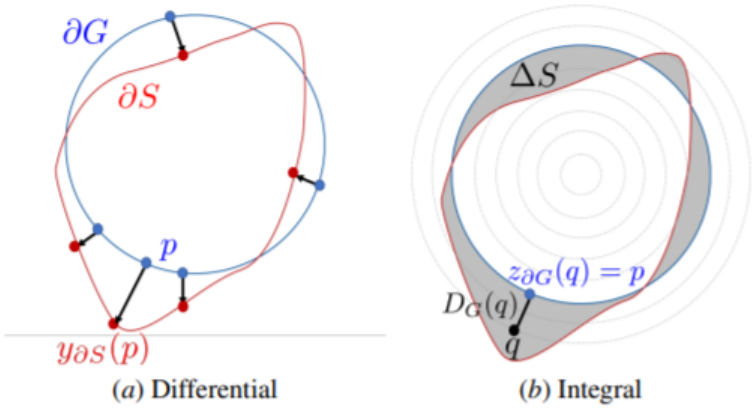
Boundary Losses

Problem: Highly Unbalanced Classes in Segmentation:



(a) Ground truth (b) GDL (c) GDL w/ boundary loss

Idea of H. Kervadeca et al. - use new boundary loss:



(a) Differential (b) Integral

G - true seg, S - predicted seg.

$$Loss = dist(\partial G, \partial S) = \int_{\partial G} \|y_{\partial S}(p) - p\|^2 \, dp \sim$$

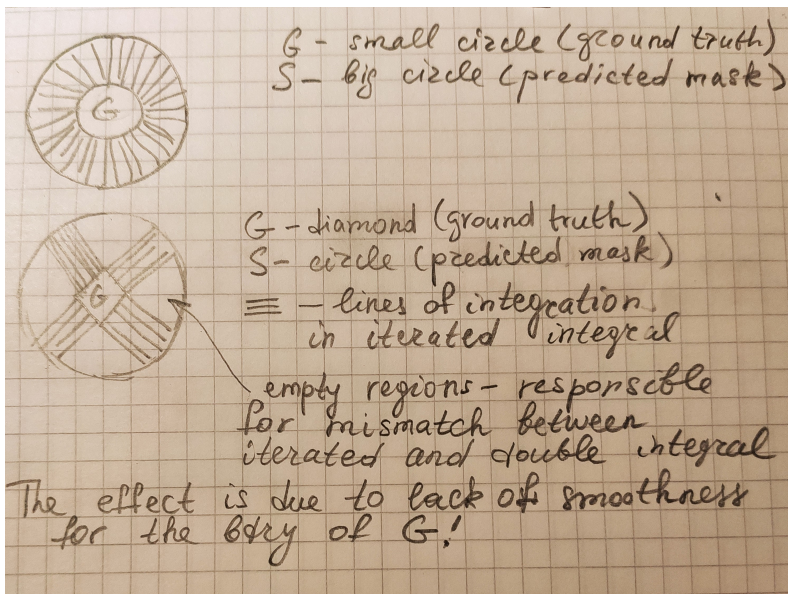
$$\int_{\Omega} \phi_G(x)(1_S(x) - 1_G(x)) \, dx.$$

What we did?

1. We considered more general loss:

$$dist_k(\partial G, \partial S) = \left(\int_{\partial G} \|y_{\partial S}(p) - p\|^k \, dp \right)^{\frac{1}{k}}.$$

2. Got insight into the difference between $\int_{\partial G} \|y_{\partial S}(p) - p\|^k \, dp$ and $\int_\Omega \phi_G(x)(1_S(x) - 1_G(x)) \, dx$:



3. Reduced the loss to a more standard form

$$Loss_k(\theta) = (dist_k(\partial G, \partial S_\theta))^k = k \int_\Omega D_G^{k-1}(x) |1_G(x) - p_{S_\theta}(x)| \, dx,$$

What we did?

4. Clarified the connection to the losses from the paper by D. Karimi et al., 2019.

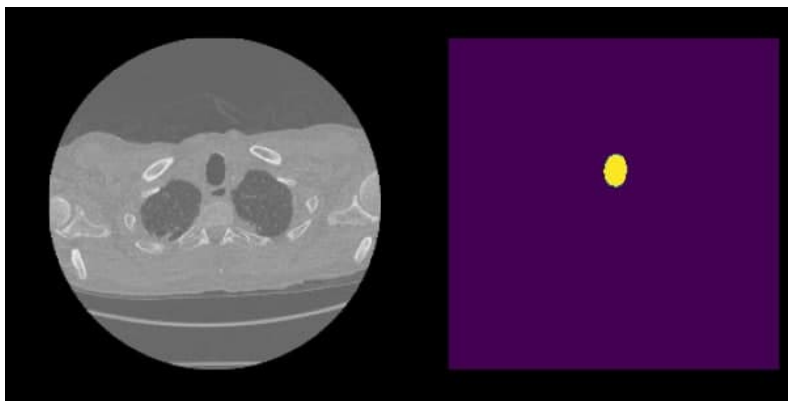
$$SymLoss_k(\theta) = max\Big\{k\int_\Omega D_G^{k-1}(x)|1_G(x) - p_{S_\theta}(x)|\,dx, k\int_\Omega D_{S_\theta}^{k-1}(x)|1_G(x) - p_{S_\theta}(x)|\,dx\Big\},$$

$$SumLoss_k(\theta) = (dist_k(\partial G, \partial S_\theta))^k + (dist_k(\partial S_\theta, \partial G))^k =$$

$$k\int_\Omega D_G^{k-1}(x)|1_G(x) - p_{S_\theta}(x)|\,dx + k\int_\Omega D_{S_\theta}^{k-1}(x)|1_G(x) - p_{S_\theta}(x)|\,dx.$$

5. Implemented the losses: $Loss_k(\theta)$, $SymLoss_k(\theta)$, $SumLoss_k(\theta)$ in code.
6. Ran the tests on chest ct-segmentation dataset

Oh my god, it works!



What we did?

Comparison

Metrics	**Dice**	**Dice+SumBndry**
dice	0.6006	0.5879
iou	0.4384	0.4246
loss_bce	0.0282	0.02
loss_bndry	0.2326	0.23339
loss_dice	0.3994	0.4121
loss_iou	0.5616	0.5754

Plans:

1. Do careful tests;
2. Optimize the performance;
3. Embed the new losses into catalyst-team libray.

References:

1. Hoel Kervadeca, Jihene Bouchtibaa, Christian Desrosiersa, Eric Grangera, Jose Dolza, Ismail Ben Ayed, "Boundary loss for highly unbalanced segmentation", Proceedings of Machine Learning Research 102:285–296, 2019.

2. D. Karimi and S. E. Salcudean, "Reducing the Hausdorff Distance in Medical Image Segmentation With Convolutional Neural Networks," in IEEE Transactions on Medical Imaging, vol. 39, no. 2, pp. 499-513, 2020. arXiv1904.10030

Project's GitHub:
https://github.com/antonsavostianov/bdry_loss

Thank you!