GeoLS: Geodesic Label Smoothing for Image Segmentation

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Take-Home Message

Proposal: An algorithm to integrate image-context information in label smoothing process

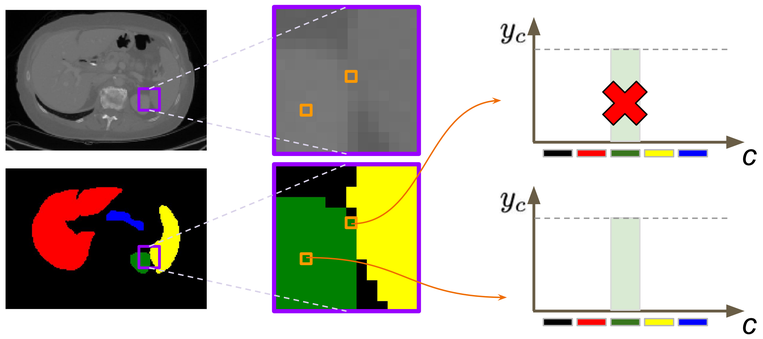
- It integrates image-aware distribution through Geodesic maps
- captures inter-class relationships in the label space

Results:

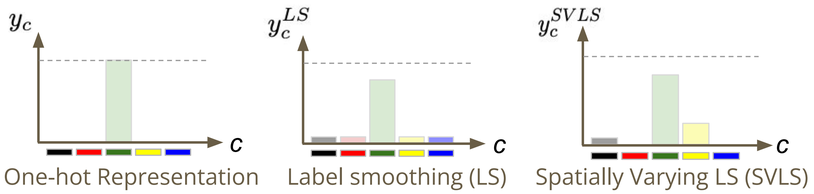
- GeoLS consistently provides superior segmentation performance over LS [1] and SVLS [2]
- Our method improves segmentation in challenging regions

Introduction

- Cross-entropy loss is commonly used to train segmentation models
  - Ground-truth (GT) represented as One-Hot (OH) labels
  - OH labels **ignore spatial and class-wise** relationships



- Soft labels capture inter-class relationships
  - e.g., Label Smoothing (LS) [1], Non-uniform LS [3]
  - [1, 3] **ignore spatial relationship**
  - **Spatial-aware** approaches: Dilating labels [4], SVLS [2]



- Problem:
  All these methods
  - **rely on target mask**
  - ignore **image intensity** information
- Idea: Integrate **image-context** information in label smoothing process
- How: Leverage **Generalized Geodesic Distance Transform (GGDT)** to obtain image-aware distribution

Method

A novel **Geodesic label smoothing (GeoLS)** method to capture **spatial relationship** between classes, and embed **image-context**

- Geodesic distance from each voxel v in image x_i to seed set $\mathcal{S}$ is obtained using GGDT [5]

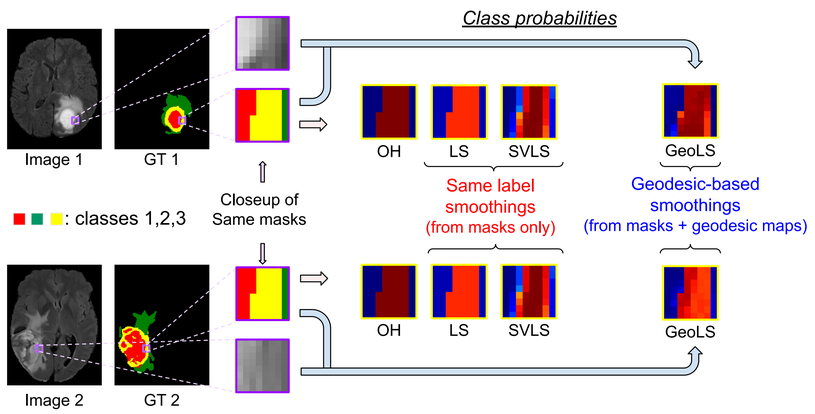
$$D_c(v; \mathcal{S}, x_i) = \min_{v' \in \mathcal{S}} d(v, v'),$$

$$\text{with: } d(v, v') = \min_{p \in P_{v,v'}} \int \sqrt{||p'(s)||^2 + \gamma^2 (\nabla x_i \cdot u(s))^2} ds$$

where $P_{v,v'}$ is all paths between v and v', $u(s)$ is the unit vector and γ controls the contribution of the Geodesic and Euclidean distance

- Normalize the geodesic maps : $\tilde{g}_c = \frac{g_c}{\sum_c g_c}$
- Our proposed geodesic label smoothing : $y_c^{GeoLS} = (1 - \alpha) y_c + \alpha \tilde{g}_c$ where α is a smoothing factor
- Code: https://github.com/adigasu/GeoLS

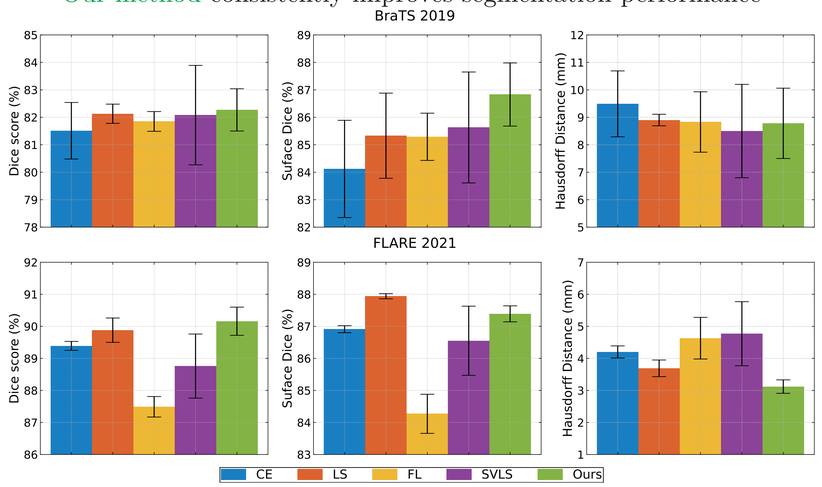
Comparison of Soft labels



Results

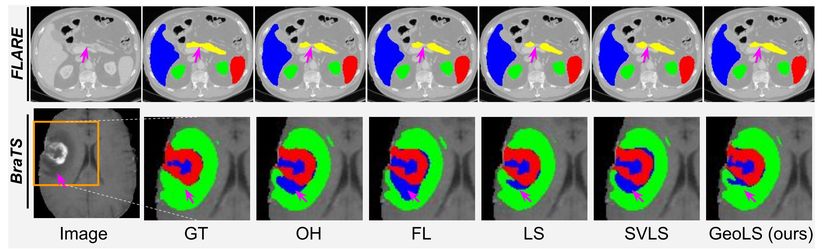
(1) Quantitative Performance

Our method consistently improves segmentation performance



(2) Qualitative Results

GeoLS minimizes the misclassification errors in challenging regions



References

[1] C. Szegedy, V. Vanhoucke, S. Ioffe, J. Shlens, and Z. Wojna. Rethinking the inception architecture for computer vision. In *CVPR*, 2016.
[2] M. Islam and B. Glocker. Spatially varying label smoothing: Capturing uncertainty from expert annotations. In *IPMI*. Springer, 2021.
[3] A. Galdran, J. Dolz, H. Lombaert, I. Ben Ayed, H. Chakor, et al. Non-uniform label smoothing for diabetic retinopathy grading from retinal fundus images with deep neural networks. *in TVST*, 2020.
[4] E. Kats, H. Greenspan, et al. Soft labeling by distilling anatomical knowledge for improved MS lesion segmentation. In *ISBI*, 2019.
[5] A. Criminisi, T. Sharp, and A. Blake. GeoS: Geodesic image Segmentation. In *ECCV*, 2008.

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