Investigation of Weighted Binary Cross Entropy on Segmentation Performance of Pleural Mesothelioma on CT Scans

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Abstract

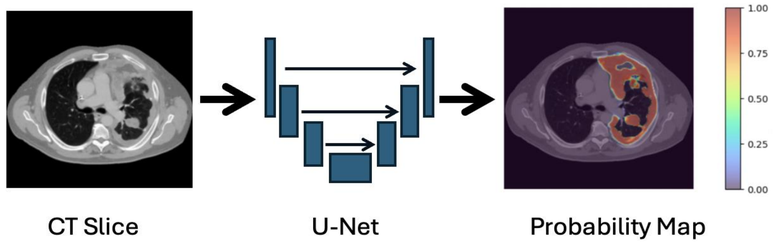
Pleural mesothelioma is an aggressive cancer of the pleural lining. Prior work has shown that no single probability threshold applied to CNN output maps simultaneously optimizes tumor-volume agreement and spatial-overlap metrics. In this study, we show that replacing binary cross-entropy (BCE) with weighted binary cross-entropy (WBCE) aligns the optimal thresholds for these two families of metrics. These findings indicate that WBCE can improve the agreement between complementary evaluation metrics.

Data Set

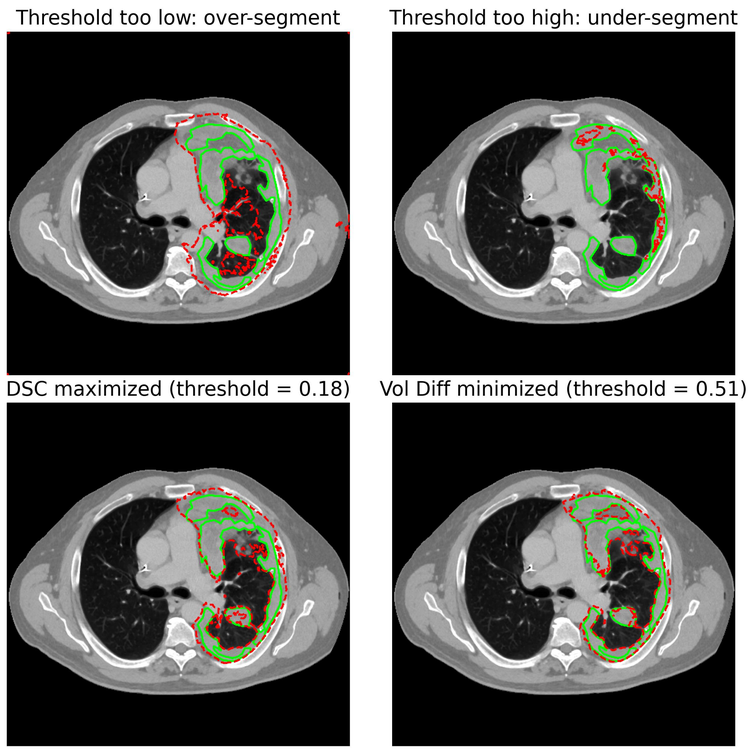
- CT scans from 126 patients with pleural mesothelioma
- Tumor regions manually contoured by a radiologist
- 96 patients for training and validation
- 30 patients held out as an independent test set

Methods

- U-Net–based convolutional neural network was used for automated tumor segmentation
- Encoder initialized with a pretrained VGG19 or ResNet50 backbone
- Network outputs a voxel-level probability map
- Probability threshold are varied to optimize segmentation metrics

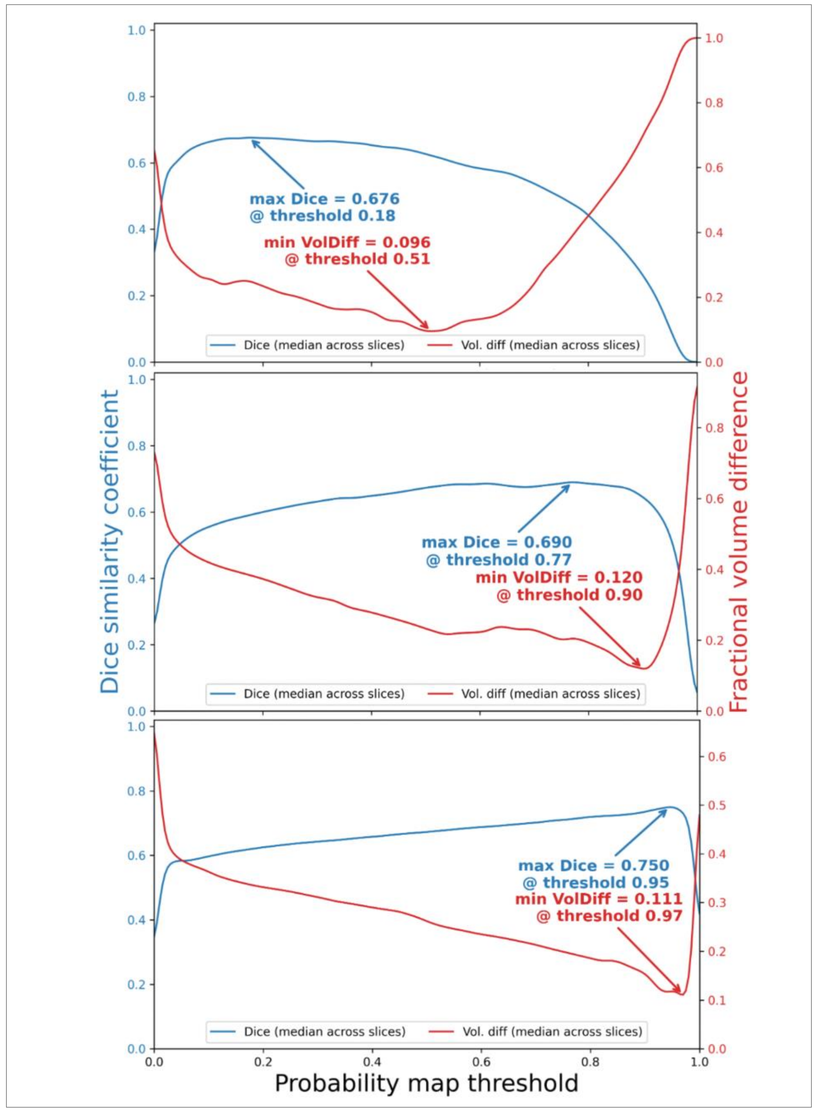


Methods



- Objective: identify a probability threshold that jointly maximizes spatial overlap (DSC) and minimizes fractional volume difference (FVD).
- **DSC =** $\frac{2|A \cap B|}{|A| + |B|}$, quantifies the spatial overlap between the reference standard A and the CNN segmentation B.
- **FVD =** $\frac{|Vol_{pred} - Vol_{ref}|}{Vol_{pred} + Vol_{ref}}$, measures the relative discrepancy between the predicted and reference tumor volumes.
- Models were trained under two loss functions:
  - $\mathbf{L_{BCE}} = -[\mathbf{y}\,\mathbf{log}(\mathbf{p}) + (\mathbf{1} - \mathbf{y})\,\mathbf{log}(\mathbf{1} - \mathbf{p})]$
  - $\mathbf{L_{WBCE}} - [\mathbf{w_1}\,\mathbf{y}\,\mathbf{log}(\mathbf{p}) + \mathbf{w_0}\,(\mathbf{1} - \mathbf{y})\,\mathbf{log}(\mathbf{1} - \mathbf{p})]$
  - where y is the reference label (0 or 1) and p is the predicted probability.
- Under BCE, the DSC-optimal and FVD-optimal thresholds do not coincide.
- Under WBCE, the two optimal thresholds converge to the same value.

Results



Conclusions

Training with weighted BCE aligns optimal thresholds, allowing a single threshold to achieve both accurate spatial overlap and volumetric agreement.

Acknowledgments

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References

Shenouda et al., Journal of Imaging Informatics in Medicine, 2024.