

Fetal Lung Segmentation in MRI Using 3D U-Net: A Comparative Study of Fine-Tuning Strategies and Anatomical Axis Reorientation

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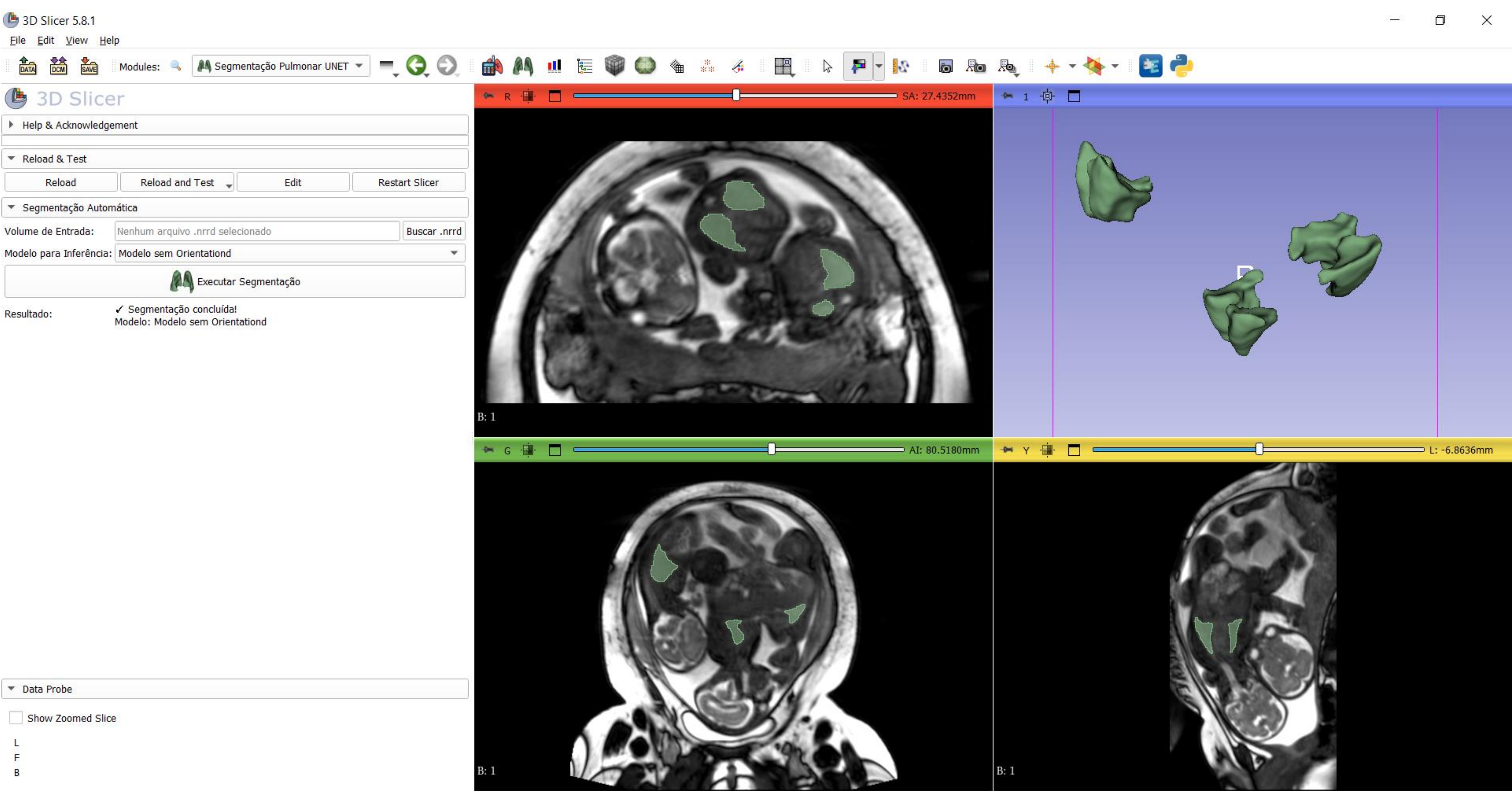
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Objective

To develop and compare four automated systems for fetal lung segmentation in 3D MRI and evaluate the impact of fine-tuning strategies and anatomical axis reorientation on segmentation accuracy.

Methods

High-resolution fetal MRI datasets were processed using the MONAI framework with a 3D U-Net architecture. Because GPU memory limitations (NVIDIA GeForce RTX 2060) prevented direct training with 1.0 mm³ spacing while preserving the required anatomical context (ROI of 256×256×160 voxels), a fine-tuning strategy was adopted using models initially trained at 1.2 mm³ spacing. Four models were developed and compared: with and without the *Orientationd* transformation—which standardizes anatomical orientation—at both 1.2 mm³ and 1.0 mm³ spacings. The two optimized 1.0 mm³ models were incorporated into a 3D Slicer module, allowing users to load images, select the desired model, and perform automatic segmentation with a single click while visualizing the resulting mask directly overlaid on the image.



Automated systems for fetal lung segmentation

Results

Model B (fine-tuned at 1.0 mm³ without *Orientationd*) achieved the best performance, with a Dice score of 0.8787 on the validation set, outperforming the 1.2 mm³ baseline (0.8701) in only 53 epochs—an improvement of +0.0086 with 52% faster convergence. For high-quality images, the models demonstrated robust and clinically relevant Dice scores. Qualitative analysis revealed complementary behavior: models without *Orientationd* showed broader lung coverage and fewer false positives, whereas models with *Orientationd* produced sharper boundaries but tended to undersegment central regions. This complementarity was particularly useful for lower-resolution images, where combining masks from both models often produced superior results.

Conclusion

Fine-tuning effectively overcame hardware limitations while preserving anatomical context and improving segmentation accuracy at higher resolution. Integration into a 3D Slicer module facilitates clinical use and immediate visual validation.