High-resolution Fetal Subplate Automatic Segmentation

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Abstract

Background:

The Subplate (SP) in the fetal brain is a transitory cytoarchitectonic compartment [1-2] that contains interstitial white matter neurons [3]. Even though this region lasts until 31 weeks of gestational age (GA) [4-5], it is critical for brain development [6], cortical circuitry and structure [2,7]. Recently, to investigate the SP volume and thickness [5,8], we developed an automatic SP segmentation model with fetal magnetic resonance imaging (MRI) using U-Net [9-10]. Howbeit, the input and output resolution of the model is relatively low (0.86 mm), which may hinder the detailed delineation of brain tissues such as the SP, cortical plate (CP) and intermediate zone (IZ) because of the small fetal brain size. Therefore, switching the previous model to high resolution is required for better SP volume and thickness measurement accuracy.

Objective:

To train a high-resolution SP segmentation model, we upsampled the previous training dataset (MRI and SP segmentation) to 0.5 mm, and refined the segmentation (Figure 1).

Material and Methods:

The study was approved by the local Institutional Review Board at Boston Children's Hospital. The total cohort for the previous model consists of 93 subjects (mean = 26.18 weeks, and sd = 2.94). High-resolution reconstruction was done using NeSVoR [11] and aligned to the low-resolution MRI to match the segmentation. The previous low-resolution MRI segmentation was upsampled via shape-based interpolation [12]. To smooth the boundary of SP and IZ in the upsampled segmentation, a novel Bivariate Gaussian Smoothing (BGS) filter was applied (Figure 2).

Results, Discussion, and/or Key Learning:

Implemented techniques generate high-quality segmentation that may reduce manual segmentation correction time; next steps include transfer-learning from an already trained high-resolution CP segmentation model to reduce subjects required for U-Net weights convergence. The high-resolution SP segmentation model can further increase the cohort's structural differences and surface smoothness, acting as a stepping stone for more accurate quantitative analysis.

Keywords: fetal, MRI, subplate, u-net, gaussian filter

Figures

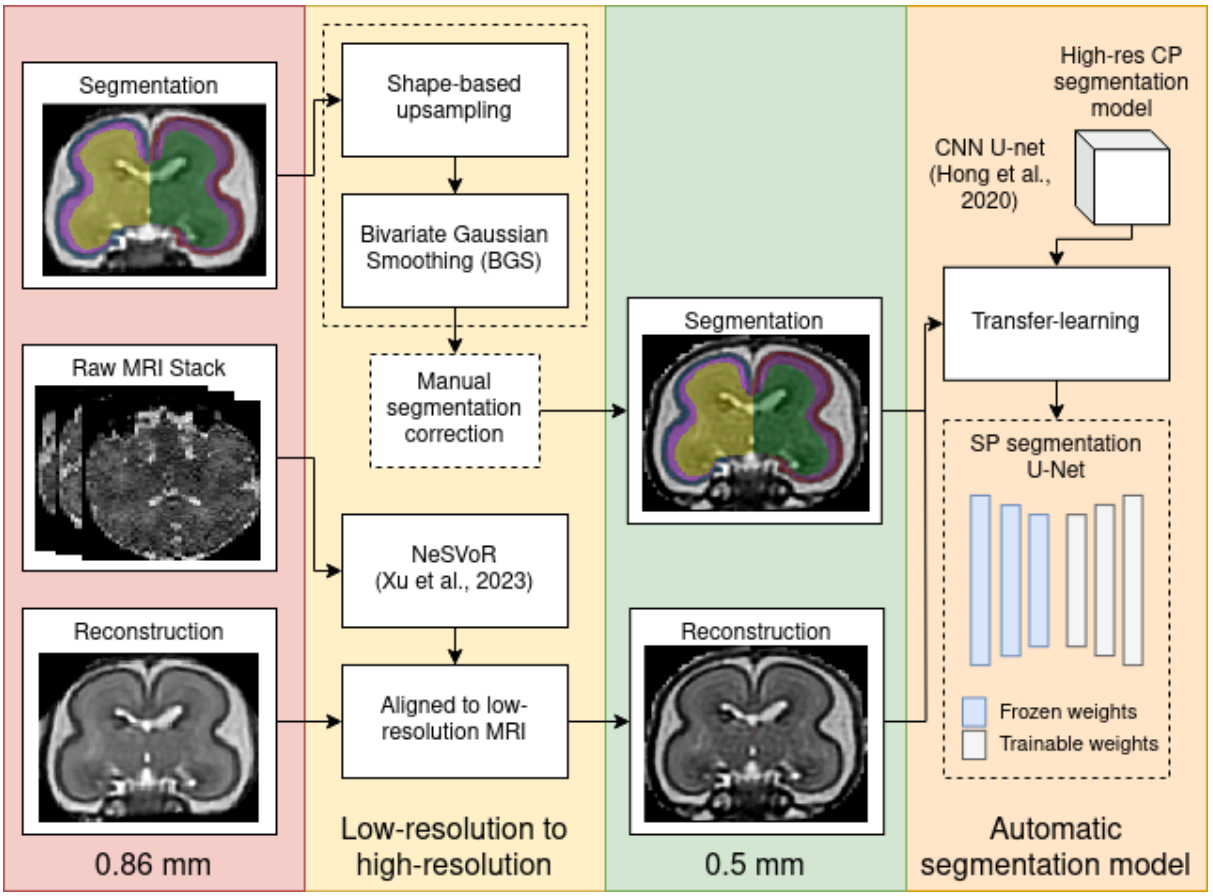

Figure 1. Automatic pipeline for enhancing voxel resolution of SP segmentation and reconstruction. High-resolution (0.5 mm) data is further used to train an automatic high-resolution SP segmentation model, leveraged via transfer-learning on an already trained, high-resolution CP segmentation model.

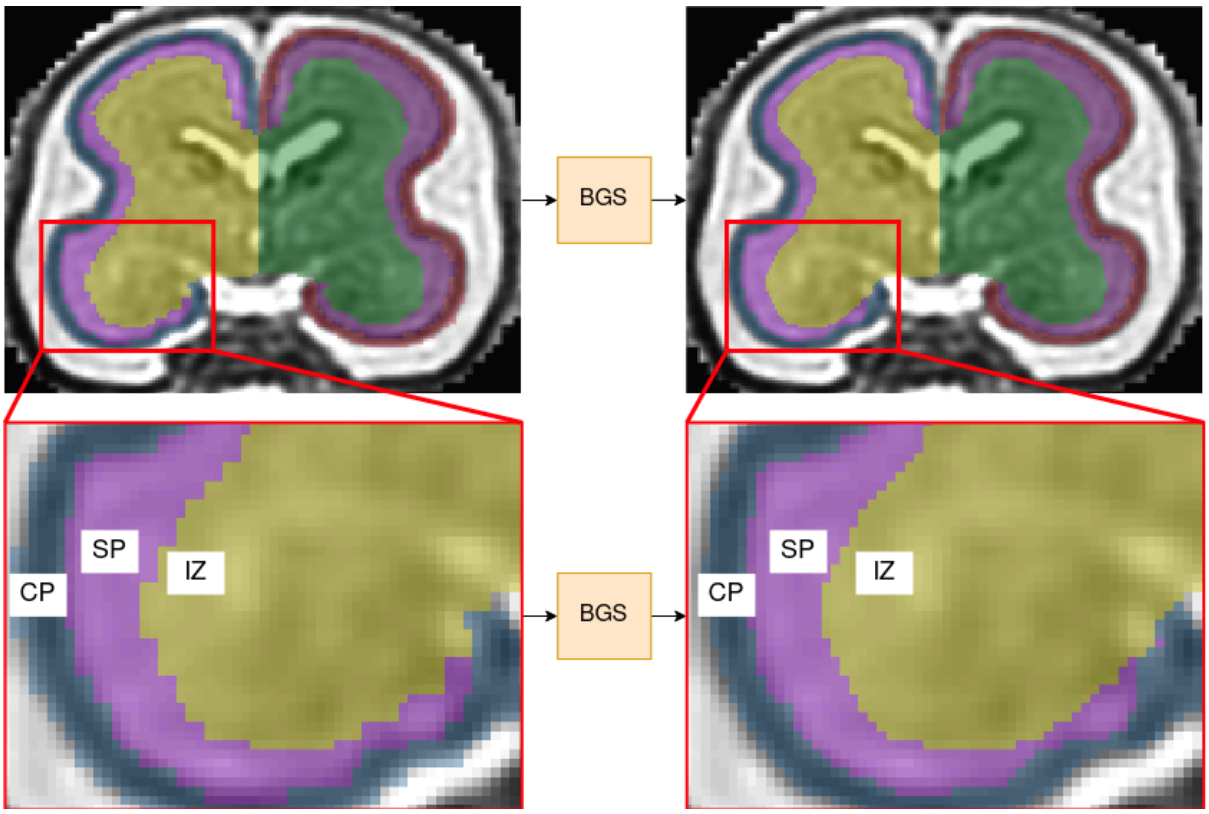

Figure 2. The Subplate (SP) region is located between the Cortical Plate (CP) and the Intermediate Zone (IZ). A novel Bivariate Gaussian Smoothing (BGS) filter was designed for IZ and SP border smoothing after segmentation's upsampling via shape-based interpolation.

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