

CNN FOR SEGMENTATION OF FETAL CORTEX IN 3D ULTRASOUND

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Abstract

Accurate and automatic segmentation of the cortex and thalamus in fetal ultrasound images can track cortical development and help predict fetal health outcomes. We propose a multi-task CNN to produce automatic segmentations from expert manual segmentations of fetal cortices and thalami. The network was trained on 32 volumes produced accurate 3D segmentations on 6 test volumes, with Dice coefficient of 0.9 on cortical and 0.7 on thalamic segmentation.

Motivation

Development of the fetal cortical plate is linked to health and cognitive outcomes after birth. A lot of work has been done in analysis of fetal brains in MRI, but much less attention has been given to brain development in ultrasound. Ultrasound presents more challenges to MRI since it displays more imaging artifacts and shows significant variability between subjects (see figure below). However, it is a routine procedure offered to all pregnant women in the developed world and there is value in automated screening of the fetal brain in US for later referral.

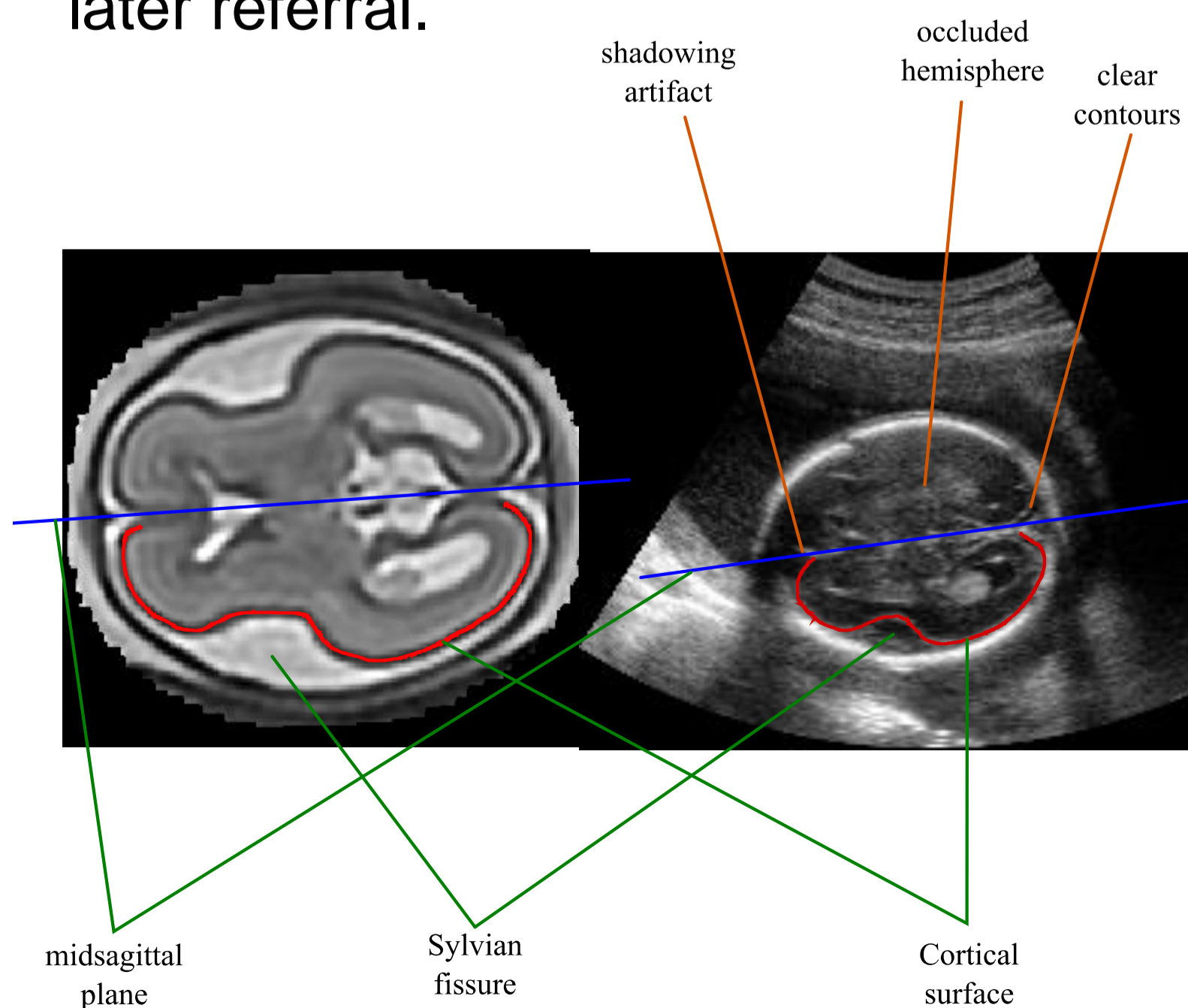
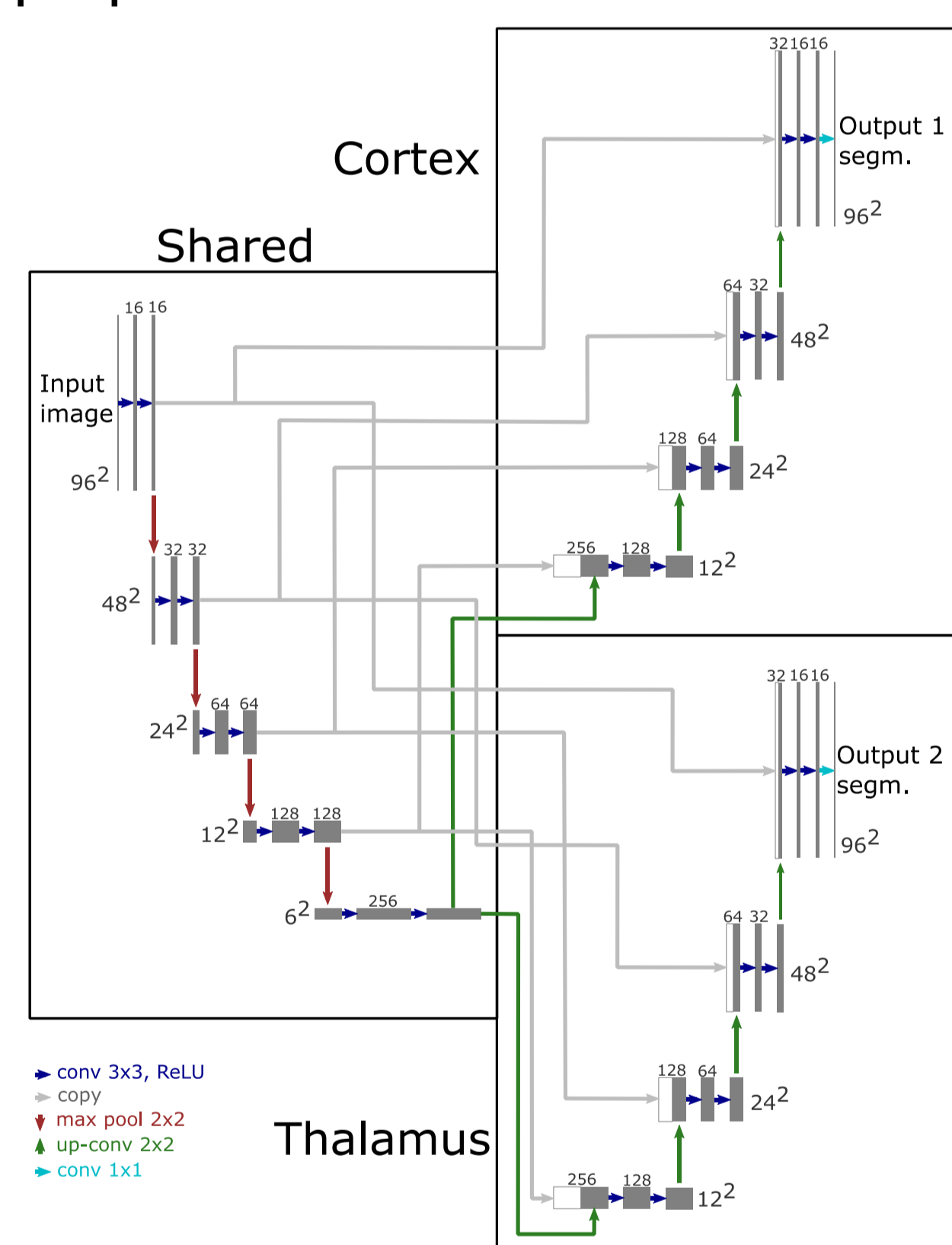


Figure: comparison of an MRI slice (23 weeks' gestation) and an ultrasound (21 weeks) of fetal brains.

Dataset

The data for this work is taken from the INTERGROWTH-21st study [1], a longitudinal study of the growth of healthy fetuses. 3D ultrasound volumes of healthy fetal brains throughout pregnancy are available for analysis. We worked on a set of 38 volumes, manually labelled by experts with the cortical plate and the thalamus. The volumes used were all resized to a resolution of 96x96x96 and co-registered but not otherwise preprocessed.



Network design

A variant of “U-net” structure [2] was used. Two output streams were used, with a shared downsampling path and separate upsampling paths for the cortex and thalamus.

A 2D network was implemented, operating on individual 2D slices from the ultrasound volumes separately. 3 different networks were trained on 2D slices. Each network was trained on a different view (sagittal, coronal and axial) sliced from the same 3D data. The outputs were then averaged. 32 volumes were used for training and 6 were left for a validation set.

Results

Each network outputs two “soft” segmentation masks for the cortex and thalamus, with each voxel given a value between 0 and 1 corresponding to the network’s confidence. Each network’s output for every voxel was averaged and a threshold was applied to obtain a joint segmentation. Combining all outputs in 3D provides better output than segmentations from any individual 2D view. A simple morphological operation was applied (a 3x3 morphological closing followed by an opening) to the resulting thresholded segmentation. The final network obtains a Dice coefficient of 0.9 on segmentation of the cortex and 0.7 on the thalamus.

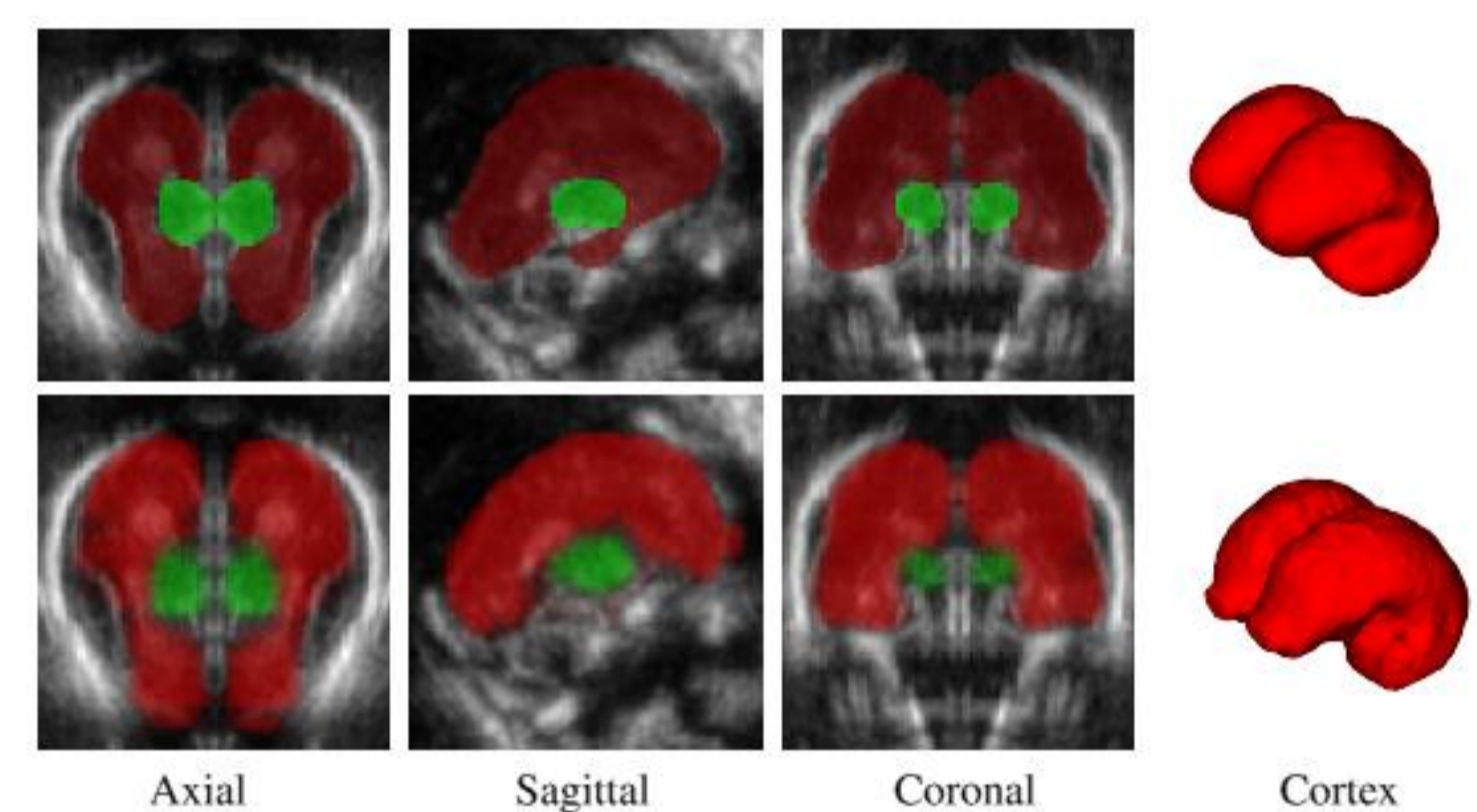


Figure: manual (top) and automated (bottom) segmentations of the cortex (red) and thalamus (green).

Future directions

Stronger priors can be included in the network structure to help guide segmentation. The labelled data is also a small subset of what is available, so using more could lead to better segmentations. The 15000 volumes in the dataset could be labelled by refining automated segmentations.

References

- [1] A. T. Papageorghiou et al, The Lancet 2014.
- [2] O. Ronneberger et al, MICCAI 2015.