Multi-task Learning for PVL detection in MRI images

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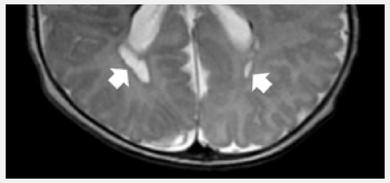
Abstract

PVL is a form of anoxic encephalopathy characterized by necrotic lesions in the periventricular white matter. Studying these small brain lesions requires expensive and time-consuming annotation. In the case of scarce data and small objects, we propose a simple and self-adapting framework on the basis of 3D U-Net to detect the small lesions and make predictions of hand function.

Introduction

Background

- Periventricular leukomalacia (PVL) is diagnosed mainly based on lesions in the periventricular white matter.
- Clinical study have found PVL commonly manifest as hand function disorder.

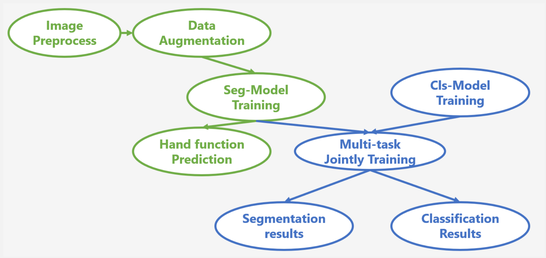


Lesions area pointed by white arrows

Project goal

- Detect white matter lesions and predict hand function based on PVL patients' MRI scans.
- Previous work using traditional image features performs poorly due to complex lesion patterns and small sample size.
- Multi-task learning: can white lesion detection help hand function prediction?

Method



Flow chart of model training: completed work in green and future work in blue

Pre-processing

- Registration, Skull stripping, Bias-field correction and image binarization.

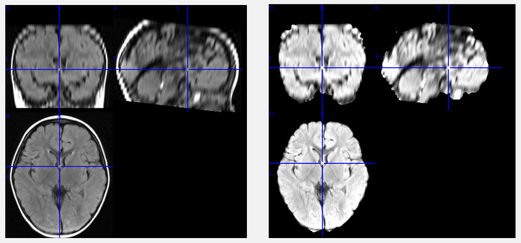
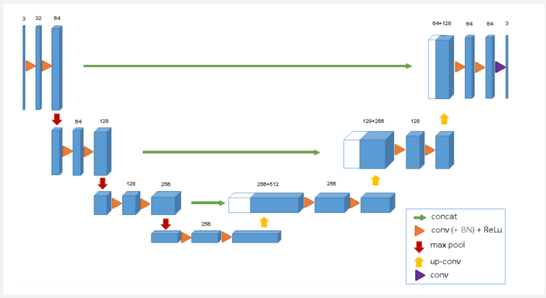


Image registration Skull stripping

PVL lesion segmentation using 3D U-Net

- Automatically adapt patch size and feature maps to data and objects.
- Train networks with a combination of dice and cross entropy loss. $L_{total} = L_{dice} + L_{CE}$

$$L_{dc} = -\frac{2}{|K|}\sum_{k\in K}\frac{\sum_{i\in I} u_i^k v_i^k}{\sum_{i\in I} u_i^k + \sum_{i\in I} v_i^k}$$



Model structure

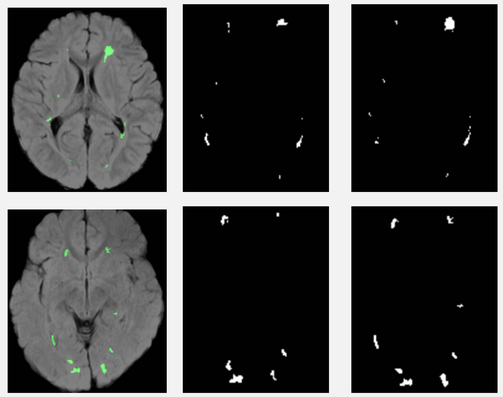
Method

Hand Function Prediction

We establish a simple model to classify the good and bad hand function.

- Apply logistic regression on the segmentation results (in matrix form) of hand-func images.

Results



Input image with ground truth overlay | 2D U-Net segmentation results | 3D U-Net segmentation results

	2D U-Net	3D U-Net
Dice	71.53	76.24
VOE	41.32	37.26

Mean dice score and volumetric overlap error of 2D and 3D U-Net

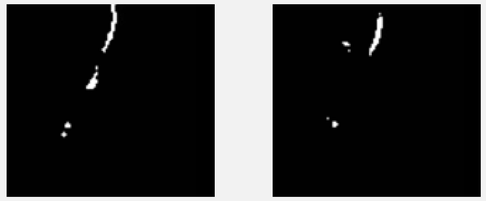
	Hand function classification
Accuracy	0.872
F1 score	0.838

Accuracy and F1 score of logistic regression model

Results of classification show a significant connection between PVL detection and hand function prediction.

Discussion

- 3D U-Net segmentation model performs well on Brian MRI images.
- High accuracy of hand function predictions indicates the high transferability between the two tasks.
- Improvement is still needed for detecting disconnected and small legion regions.

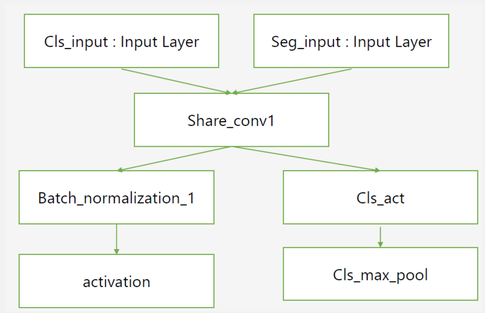


Annotations of experts | Our segmentation mask

Future Research: Multi-task Model

Plan to Jointly train a simple CNN-based classification model and segmentation model. Set loss as a combination of L_{cls} and L_{seg} and adjust weight of tasks by adjusting loss weight r

$$L_{joint} = r \times L_{cls} + L_{seg}$$



Model of joint training

Acknowledgements

Thanks to my advisor Prof.Yang Li for patient guidance. And I'm grateful to Doctor Hen Liu, Prof.Peiwu Qin , Yicong Li and Yifeng Xie. Finally, my heartfelt gratitude to Abreto.