Multiple Sclerosis Lesion Segmentation on 7T MRI: A U-Net Tool and Evaluation

M. Maynord[1], M. Liu[1],C. Fermuller[1], Y. Zeng[2], S. Choi[2], D. M. Harrison[2,3]
Computer Science, University of Maryland College Park, College Park, MD[1]
Department of Neurology, University of Maryland School of Medicine, Baltimore, MD[2]
Department of Neurology, Baltimore VA Medical Center, VA Maryland Healthcare System, Baltimore, MD[3]

#P008

Introduction

- The recent introduction of 7T MRI to multiple sclerosis has improved characterization of lesional pathology, particularly through increased resolution.
- However, due to unique signal characteristics and scanner artifacts, existing methods for automatic lesion detection do not translate well to 7T MRI. For this reason, no standardized, universal, and well validated tool for automated 7T MRI MS lesion segmentation exists.
- Existing work on MS lesion detection in 7T scans includes work with MP2RAGE acquisitions, [1, 2] despite the more typical use of FLAIR for lesion quantification in MS research.
- Here we explore state-of-the-art methods in Deep Learning applied to the task of 7T white matter lesion (WML) segmentation on FLAIR, with plans to provide a tool for 7T WML to the MS research community.

Methods

- 144 7T MRI scans collected in an ongoing MS research study at the University of Maryland, Baltimore were utilized for this project. FLAIR images, acquired at 0.5 x 0.488 x 0.488 mm3 resolution underwent initial WML segmentation using the Lesion Segmentation Tool (LST) [4] implemented in SPM.
  - We employ the LPA algorithm from LST, since we only used FLAIR images as input. LPA generates a lesion probability map, with the intensity of each voxel varying between 0 and 1. For the White Matter Lesion (WML) mask, we applied a threshold value of 0.3.
- WMLs masks were then manually edited for accuracy by expert raters. These final WML masks were considered as 'gold standard' masks and utilized for model training and comparison.
- 72 scans were used for training and 72 were reserved for model validation.
- We utilized a variant of the conventional U-Net architecture [3] for image segmentation, where the encoder portion of the U-Net is replaced with a Transformer network.
  - Transformers are a relatively recent development in Computer Vision, differentiated from the previous approach of Convolutional Neural Networks (CNN) in its use of long range attention relations. With this mechanism for connecting spatially separated portions of the input, tranformers are coming to outperform CNNs.
  - The model is applied patchwise, and we apply a number of data augmentations including: random flipping, random cropping (with bias towards lesions), random rotations, random intensity alterations.
- Final model outputs and initial LST output masks were tested against the gold standard masks using the Dice Similarity Coefficient (DSC).

Results

- A Transformer+CNN U-Net model attained a DSC of 0.64 over the validation set for WML segmentation. In comparison, the initial LST output masks attain a DSC score of 0.36 over the same validation set. We compare against LST output:
  - Common errors occurring with LST segmentation included: masking of 1) hyperintense regions of cortical gray matter, 2) ependymal lining, and 3) choroid plexus as lesion, in addition to 4) regions of heterogeneous white matter signal.
  - LST errors were mostly overcome using the Transformer+CNN U-Net model.

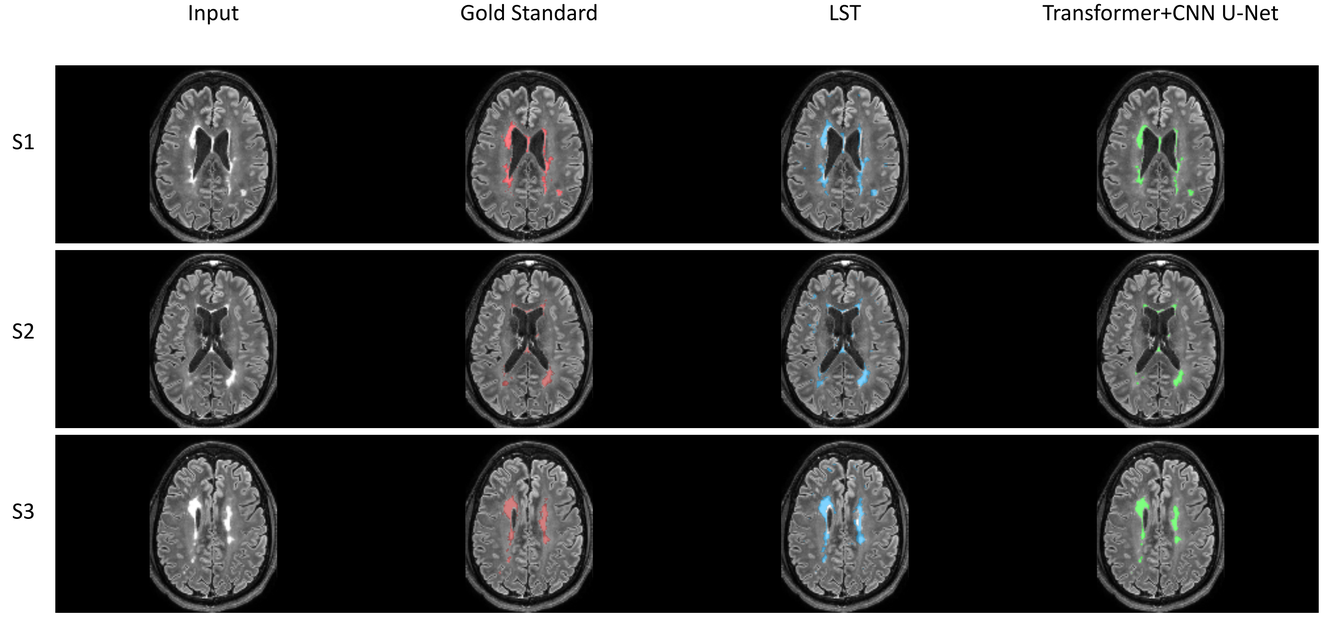

Figure 1: Comparison of lesion segmentation methods. Shown is a sample 7T FLAIR scan at three representative slices (S1, S2, S3) from an MS subject. On S1, S2, and S3, note incomplete filling of WML boundaries by LST and multiple areas erroneously masked by LST at the cortical ribbon (likely due to the hyperintense nature of the cortical ribbon on 7T FLAIR). On S2, also note erroneous masking of portions of the choroid plexus as WML. Also note erroneous masking of multiple areas of inter-lesional heterogeneous white matter by LST in S1 and S3.

Discussion

- Fully automated MS WML detection on high resolution 7T FLAIR images was feasible using a Transformer+CNN U-Net model. This model performed well compared to manual lesion masks and was superior to an existing WML segmentation algorithm.
- We plan to further develop this tool for use on all 7T MRI images and make it available for future public use.

References

1. La Rosa, Francesco, et al. "Multiple sclerosis cortical lesion detection with deep learning at ultra-high-field MRI." *NMR in Biomedicine* 35.8 (2022): e4730.
2. Fartaria, Mário João, et al. "Automated detection and segmentation of multiple sclerosis lesions using ultra–high-field MP2RAGE." *Investigative radiology* 54.6 (2019): 356-364.
3. Hatamizadeh, Ali, et al. "Unetr: Transformers for 3d medical image segmentation." *Proceedings of the IEEE/CVF winter conference on applications of computer vision*. 2022.
4. Schmidt, Paul, et al. "An automated tool for detection of FLAIR-hyperintense white-matter lesions in multiple sclerosis." *Neuroimage* 59.4 (2012): 3774-3783.

Funding & Disclosures

MRI acquisition was funded by NIH 1R01NS104403-01 and funding from Roche-Genentech.

Dr. Harrison has received consulting fees from Horizon Therapeutics, TG Therapeutics, and EMD-Serono and royalties from Up To Date, Inc.

Dr. Harrison has received research funding from EMD-Serono and Roche-Genentech.