Automatic Multiple Sclerosis Lesion Tracking Using Unsupervised Machine Learning

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1 Introduction

Isomap and Locally Linear Embedding (LLE) are Non-Linear Dimensionality Reduction (NLDR) techniques used to present high dimensional data in an appropriate lower dimension, while retaining information and minimizing variance. We use the NLDR methods for identifying and tracking Multiple Sclerosis (MS) brain lesions from magnetic resonance images (MRI). MS is an autoimmune disease that attacks the central nervous system and currently not completely understood. Specifically we automatically segment gadolinium (Gd)-enhancing lesions with Gd enhancements (Gd Volume greater than 2 ml). Deep Learning models like Convolutional Neural Networks (CNN) have been shown to be able to recognize features and perform image segmentation of different lesions. We will address three major concerns with deep learning models. First is that running deep learning models are computationally expensive, thus requiring a powerful computer to run on. Regardless of the computer specifications, training a deep learning model can still be challenging in several respects to get the optimal results in medical research. Secondly, deep learning models require a lot of examples or data to train on in order to achieve the best accuracy. Lastly, CNN's are good with extracting global features and detecting large lesions. However, CNN"s may struggle with multi-scale local features, thus making it hard to track MS lesions which can be small and sometimes indistinguishable from white matter. This work addresses these concerns by utilizing NLDR techniques to perform MS lesion tracking on brain MRI images.

2 Materials and Methods

The data used in this work comes from deidentified UT Health patients with multiple sclerosis. The MRI dataset used consisted of T1 pre-contrast (T1-pre), T1 post-contrast (T1-post), T2 weighted (T2w), Fluid Attenuated Inversion Recovery (Flair), and proton density (PD) images. We included T1-pre, T2w, Flair, and PD modalities as a 4-D image into our NLDR methods. As our ground truth, we subtracted T1-post and T1-pre images to get a new image termed subimage. With 5 MRI sequences for each patient, 52 images per modality, our dataset consisted of 260 images in total.
With 4-D images consisting of T1-pre, T2w, Flair, and PD images, we used Isomap and LLE to reduce the dimensions to a 2-D image space. the hyperparameters for both methods were optimized. A binary image is then constructed from the NLDR, resulting in pixel values related to MS lesions. Then we selected a region of interest for each image to remove any remaining artifacts not pertaining to MS lesions. The performance of our NLDR method was evaluated by calculating dice similarity coefficient (DSC).

3 Results

We applied our proposed method on 260 images and achieved a DSC score greater than 0.80 with both Isomap and LLE methods. All results were compared to a subimage of their respective T1-post and T1-pre images we labeled as our ground truth. To get the final predictions of the NLDR a binary image is constructed, including pixel values related to MS lesions. We removed any noise from the binary images to maximize performance. We tested neighborhood sizes consisting of 30, 45, 60, 70, 75, and 80 neighbors and found that 70 neighbors worked best for both NLDR methods.

4 Conclusion

We demonstrated that using NLDR for MS lesion tracking resulted in excellent DSC. The results of our experiment showed it is possible to track MS lesions in brain MRI images with unsupervised learning. Results needs to be further investigated with a large sample size. A 2019 study done by the National MS Society shows that the number of veteran3s with MS has doubled in the past few decades, yet only 40% receive the proper care. Our method creates a viable option for tracking MS lesions using only brain MRI in an unsupervised manner and potentially other applications as well. This would advantageous to use, where other methods may require training, supervision and data labeling.