Knowledge-Driven Automated Segmentation of Cortical Lesions on MR Brain Images in MS

S. Datta[1], J. S. Wolinsky[2], and P. A. Narayana[1]
[1]Diagnostic and Interventional Imaging, The University of Texas Medical School at Houston, Houston, Texas, United States, [2]Neurology, The University of Texas Medical School at Houston, Houston, Texas, United States

Introduction:

Multiple sclerosis affects both white matter (WM) and gray matter (GM). Conventional MR imaging is widely used to assess T2 hyperintense lesions in WM. These techniques are suboptimal in detecting cortical lesions. Recently, double inversion recovery (DIR) and phase sensitive inversion recovery (PSIR) have been shown to increase the confidence with which cortical lesions can be visualized with higher confidence than the conventional sequences [1]. However objective quantification of cortical lesions is still challenging because of their locations, relatively poor lesion-to-tissue contrast ratio, shape and size. Here we report a knowledge-driven segmentation with minimal human intervention for quantification of cortical lesions.

Image Acquisition:

Magnetic resonance (MR) brain images on 10 MS subjects were acquired on 3T Philips intera scanner with a dual quaser gradient system with a SENSE factor of 2. As a part of routine protocol, dual fast spin echo (FSE) (TE1/TE2/TR = 8.2 ms/90 ms/6800 ms), fluid attenuated inversion recovery (FLAIR) (TE/TR = 80 ms/10002 ms), double inversion recovery (TE/TR = 32 ms/15000 ms), and phase sensitive inversion recovery (PSIR) (TE/TR = 8 ms/4500 ms) images were acquired. All the images were acquired with a field of view 256 mm x 256 mm and a matrix size 256 x 256.

Methods:

FLAIR, DIR, and PSIR images were co-registered with FSE using rigid body registration. Extrameningeal tissues in the FSE images were removed using in-house developed semi-automated software and this mask was applied to FLAIR, DIR, and PSIR images, followed by intensity inhomogeneity correction [2]. Normal tissues along with T2 hyperintense lesions in WM were classified on FSE and FLAIR images using the unified approach [2]. Cortical lesions were identified and classified on DIR images by exploiting their locations on DIR and PSIR images. Morphological grayscale reconstruction algorithm [3, 4] was applied on DIR images to identify regional maxima. A regional maximum is a set of connected voxels such that any voxel in the neighborhood of the region will have lower intensity relative to every voxel present in the region. The original image (I) is initially decomposed using grayscale erosion with a structuring element, S, to obtain an image, I' such that the intensity of each voxel in new image is lower than the corresponding voxel present in the original image. Following the decomposition, an elementary geodesic dilation, $\delta_I^{(1)}(I')$, is applied to I' by first dilating the image with the structure element, followed by the point-wise minimum with the image I, which is represented as

$$\delta_I^{(1)}(I') = (I' \oplus S) \wedge I$$

where, $\oplus$ and $\wedge$ represent the morphological dilation and point-wise minimum operators. By performing the elementary geodesic dilation repeatedly n times until there is no change in the resulting image, the grayscale morphological reconstruction of image, I', by dilation is obtained as

$$\delta_I^{(n)}(I') = \delta_I^{(1)} \circ \delta_I^{(1)} \circ \ldots \ldots \circ \delta_I^{(1)}(I').$$

The regional maxima are obtained by subtracting the reconstructed image from the original image, I. The set of regional maxima obtained consists of both cortical and WM T2 hyperintense lesions. The WM lesions are removed by masking the lesion classification obtained with FSE and FLAIR images as described in [2]. Finally, the cortical lesions are extracted on both DIR and PSIR images and verified by an expert.

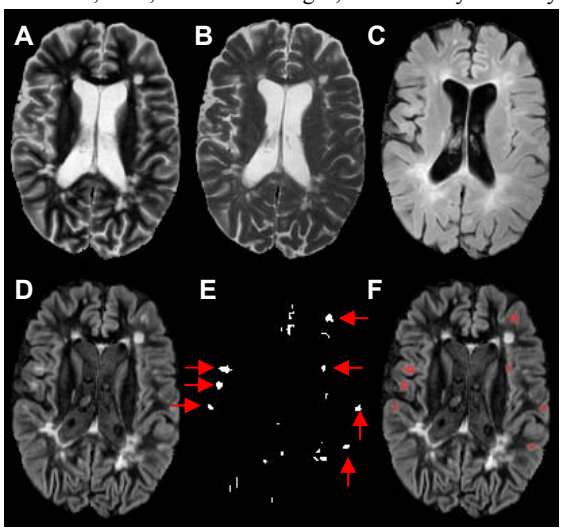

Fig. 1: A: PSIR magnitude reconstructed; B: T2; C: FLAIR; D: DIR; E: regional maxima obtained with the application of morphological grayscale reconstruction; (F) operator selected cortical lesions superimposed on DIR images.

Results and Discussion:

Figure 1 shows the PSIR-magnitude reconstructed (A), T2-weighted (B), FLAIR (C), and DIR (D) images. The image obtained following the identification of regional maxima and removal of T2 hyperintense lesions is shown in Fig. 1E. This image consists of cortical lesions and a few false classifications. Based on both PSIR and DIR images simultaneously, the expert selected segmented cortical lesions (red arrows on Fig. 1E). These lesions are shown superimposed on DIR images (Fig. 1F). As can be observed from this superimposed image, the proposed algorithm preserved the shape and size of cortical lesions.

Conclusions:

We have presented a technique for the classification of cortical lesions with minimal human intervention. All the processes are automated except for the identification and elimination of the false positives by the expert. The operator involvement involves only in the identification and cancellation of the false positives as the final step. This eliminates the bias associated with manual delineation of lesions. To the best of our knowledge, the proposed technique is the first attempt in cortical lesion segmentation with minimal human intervention.

Acknowledgment: This work was supported by the NIH Grant EB002095.

References: **[1]** Nelson et al. Am J Neuroradiol. 2007;28:1645-1649; **[2]** Sajja et al. Ann. Biomed. Engg. 2006;34:142-151; **[3]** Datta et al. J Magn. Resonan. Imag. 2007;25:932-937; **[4]** Soille P. Morphological Image Analysis. Springer-Verlag; New York: 2003.