

Building a Probabilistic Anatomical Brain Atlas for Multiple Sclerosis

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We present a completely automatic method to build an average anatomical brain model of Multiple Sclerosis (MS) using a set of magnetic resonance images. Brain shape variations between subjects were identified using segmented images where White Matter Signal Abnormalities (WMSA) and Normal Appearing White Matter (NAWM) jointly defined the White Matter (WM) anatomical extent. Differences due to linear transformations were excluded, resulting in the quantification of pure morphological differences. The result is an average shape image representing MS brains characteristics. Shape variations around this mean are produced, allowing statistical analysis of the extent of brain configuration changes in MS.

Introduction An important tool used to diagnose abnormal anatomical variations are medical atlases. Computerized atlases comprising information in a more practical and quantitative manner than paper atlases are becoming available. They usually include information obtained from a large set of subjects and are sometimes built using methods that enable the quantitative analysis of shape variations in a given population. While the construction of computerized atlases is now under investigation by several groups and more disease-specific models are becoming available, there is a lack of resources dedicated to the construction of computerized anatomical atlases for pathologies where MR images comprise WMSA. Though there are various reasons for this, our group's primary obstacle has been the presence of WMSA which bias the registration procedure at the base of our atlas method. This work is a first attempt at circumventing this problem and produce an atlas of average brain shape and variations for MS.

Methods Our method to build anatomical brain atlases is based on a fully automatic intensity-based registration procedure [1]. It can be summarized as follows: 1) Affine registration between a set of MR scans from a group of subjects and a reference image corrects for positioning and global shape differences due to translation, rotation, scaling and shearing; 2) Local deformable intensity-based registration is then used to evaluate residual variations due to pure morphological differences and produce images having the same shape as the reference image for every subject; 3) Averaging the residual deformations and the locally registered images yields an average deformation and an average intensity image, respectively; 4) The average deformation is then applied to the average image to produce the model. It presents an average shape corresponding to the characteristics of the set of MR scans under investigation. While this method is well suited to deal with images without signal abnormalities, images containing WMSA, such as is the case in MS, bias the deformable registration procedure (step 2) and thus the characteristics of the resulting probabilistic models. To circumvent this problem, we applied the algorithm to segmented images where WMSA and NAWM were considered as 1 tissue class. The registration is then performed on segmented images containing only normal tissue types (Cerebro-Spinal Fluid (CSF), White Matter (WM), Gray Matter (GM)). The resulting models are thus not influenced by bad correspondences due to lesions, while still reflecting anatomical shape variations.

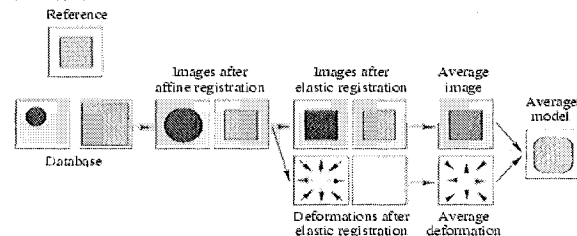


Figure 1: Atlas construction procedure. Images from patients are symbolized by the black circle and the gray square.

Data Double-echo SE brain MRI from 20 patients suffering from clinically definite MS were acquired (3000 ms/30 ms; 80 ms/0.5 (TR/TEs/NEX)) using a 24cm FOV and a 256x192 matrix. 52 slices were acquired for each scan, resulting in images with a voxel-size of

0.94x0.94x3mm³ (See [2] for information on data acquisition). Images were subsequently processed with Template Driven Segmentation (TDS) [3] to provide NAWM, GM, CSF and WMSA segmentations for each subject (Fig. 2a). Partial Volume Correction (PVC) [2] was performed and WMSA intensity values in the resulting images were then replaced by the NAWM signal intensity value (Fig. 2b).

Results and Discussion The atlas construction method was applied to the segmented images, producing the average model in Fig. 2c. 4 models were built by iterating the procedure described in Fig. 1 using the model of the previous iteration as the reference image for the current iteration (The reference image at the first iteration was a randomly selected subject amongst the 20 patients). The correlation coefficient between successive models are 0.913, 0.998, 0.999, 0.999. The relatively low value of the first coefficient compared to the following ones stresses the fact that the first reference image is quite different in appearance from the following average models. The high correlation between models are in accord with previous results [1] showing that the models are stable with regards to the number of iterations and represent the true average shape of the group of subjects. T² statistics were also computed at every voxel between different models to assess their shape differences. The highest p-value between models 1 and 2 was 0.29, and 0.87 between models 2 and 3, showing the high shape correspondence between models. An example use of the resulting statistics on variability is to identify regions of large shape variations within the group of patients. For this, the determinant of the covariance matrix obtained from the deformable registration displacements are displayed in Fig. 2d. This result can be interpreted as an image of probabilistic volumes. Hence, for a given voxel, a large intensity corresponds to a large variability in the positions of corresponding voxels found in each image. Note that the largest variations are symmetric and in the regions surrounding the frontal and posterior aspects of the lateral ventricles, which are known to present large shape variations due to the presence of lesions and brain atrophy. The corpus callosum also appears to be outlined by this method, consistent with the strong involvement of this

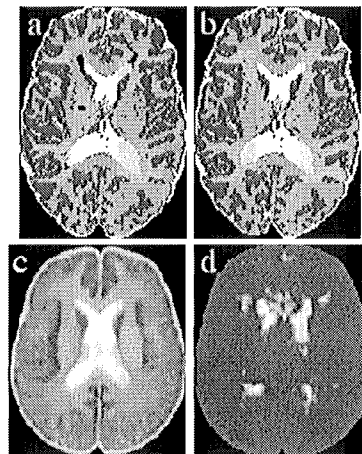


Figure 2: a) Result of TDS+PVC on 1 subject. b) WMSA and NAWM define WM c) Average model. d) Regions of large variations. structure in MS [4].

The coupling of such a high quality model with statistical information regarding shape variability is presently under investigation to identify areas of abnormal shape variations between groups of subjects, in particular between normal subjects and MS patients.

References

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