

Model-based Automatic Detection of the Anterior and Posterior Commissures on MRI Scans

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Introduction

A model-based fully automatic algorithm is presented for detection of the anterior and posterior commissures (AC/PC) on 3D MRI scans. Knowing the locations of these landmarks is important for FOV placement during image acquisition, and in the development and application of post-acquisition computerized image analysis (e.g., segmentation and registration). The present algorithm has several advantages over previously published methods for solving this problem. It is fast, accurate, and robust in the presence of noise and other image artifacts. It does not rely on any specific image contrast or location of the corpus callosum. For example, it can be trained to detect the AC/PC on both T1 and T2-weighted images. It is flexible in its definition of these landmarks (e.g., center versus edge of the AC/PC cross-section with the mid-sagittal plane (MSP)). It relies on a relatively small number of parameters whose default values rarely need to be changed.

Materials and Methods

The algorithm presented in this paper involves a training phase, which is performed once for a particular class of data. The information obtained from the training data is then used to locate the landmarks on test images. Let us assume that we have available a set of M model images, and on each image we know the (x, y, z) coordinates (position vectors) of the AC, PC, the midbrain-pons junction (MPJ), and the location of the MSP. In the training phase, the following information are determined and stored in a model file: (1) the mean (over all models M) position vector of the MPJ; (2) the mean MPJ-to-PC and MPJ-to-AC displacement vectors; and (3) mean cylindrical templates about the AC, PC, and MPJ for a number of (N) different pitch angles α . This information is recalled for AC/PC detection on test images.

The AC/PC detection is performed following these steps: (1) The MSP is automatically detected using previously published methods; (2) a cylindrical search region centered around the mean MPJ position vector (determined during the training phase) is searched to detect the MPJ on the test image using normalized cross-correlation (NCC) for template matching; (3) the PC is located by searching a region centered at the point obtained by adding the estimated MPJ location in step (2) and the mean MPJ-to-PC displacement vector obtained from the training data; and (4) the AC is located in a similar manner as the PC. In steps (2)-(4), voxel v_m corresponding to the landmark in question is determined using the following optimization formula $v_m = \operatorname{argmax}_v \left[\max_{\alpha} \frac{\vec{T}_{\alpha} \cdot \vec{F}_v}{\|\vec{T}_{\alpha}\| \|\vec{F}_v\|} \right]$, where \vec{T}_{α} corresponds to the model template at pitch angle α , and \vec{F}_v denotes a vector comprised of voxel values in a cylindrical neighborhood centered about voxel v on the test image.

Experiments and Results

The algorithm was trained using six MRI scans on which the AC/PC and MPJ locations had been determined manually. Using the information obtained from this training set, the algorithm was applied to over 2000 scans acquired from different MRI scanners (manufacturers and field strengths 1.5 T and 3.0 T), pulse sequences, age groups, imaging centers, and patient populations. The landmarks were correctly determined in 99% of the cases. For a quantitative evaluation of the algorithm, we compared the automatically detected landmark locations to those determined manually on 42 scans (30 normal subjects and 12 patients with schizophrenia). The mean 3D Euclidean distances between the automatically and manually detected landmarks were 0.85 mm for the (AC) and 0.86 mm for the (PC). The maximum errors were 1.60 and 1.74 mm, respectively. Figure 1, shows a test image on which the AC (green), PC (red) and MPJ (blue) were detected automatically, along with their respective cylindrical search regions, and the automatically detected MSP.

Discussion

The mean errors estimated based on our experiments are less than one millimeter and comparable to inter-rater variability reported in the literature for manual AC/PC placement.

The training and AC/PC detection algorithms together require specification of the following parameters: radii and heights of the AC, PC, and MPJ templates and their search regions; initial pitch angle α ; number of pitch angles N ; and step size $\Delta\alpha$. All of these parameters are set at default values and are transparent to the user.

The algorithm proposed in this paper was implemented in C++ on a Linux workstation. For a typical 3D MRI scan, this implementation takes approximately 6 seconds to run on a computer with an Intel Pentium 4 CPU with a speed of 3.0 GHz and 2 GB RAM. Of this time, approximately 4.5 seconds are spent locating the MSP and the remaining 1.5 seconds are spent on AC/PC detection. This implementation of the algorithm is freely available online at www.nitrc.org/projects/art.

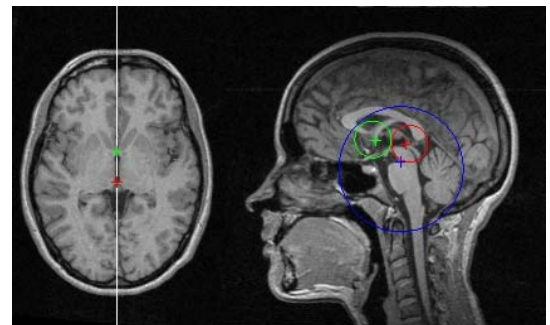


Figure 1