

AUTOMATIC BRAIN MR IMAGE REGISTRATION BASED ON TALAIRACH REFERENCE SYSTEM

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ABSTRACT

An automatic process of determining specified points in brain is presented, which is required to register brain MR images based on Talairach reference system. Generally, the 10 points that are needed to be determined for the registration are anterior commissure(AC), posterior commissure (PC), anterior point (AP), posterior point (PP), superior point (SP), inferior point (IP), left point (LP), right point (RP) and two points for the midline of the brain. The proposed method automatically determines all the necessary points for registration except IP in a more stable manner than the manual selections. Projection information of the image intensity is used for the midline determination which is a necessary step for the midsagittal plane extraction. To find AC and PC in the midsagittal plane image, two-level shape matching of the corpus callosum followed by AC and PC shape matching is performed in the edge-enhanced midsagittal plane image. Remaining points are found by fitting the intensity curve of the cutview with the gaussian model. After finding the necessary points, the brain MR images can be successfully registered.

1. INTRODUCTION

As medical research techniques improve, many imaging techniques are applied to acquire brain images for further research on human brains. MR imaging technique is especially focused lately because it is a non-invasive method and gives high resolution image. In many applications, the researchers have to register the brain MR images from different subjects or same subject with different imaging methods. Therefore, registration of the brain in accordance with some standardized space is required. One of the most frequently used registration methods for multi-modal brain images is Talairach-based approach. Talairach and Tournoux introduced a co-planar stereotaxic atlas of the human brain using anatomical information in 1988 and it has been used as a guide for brain registration thereafter [1]. In order to register brain images according to Talairach atlas, anterior commissure (AC) and posterior commissure (PC) must be selected with priority and anterior point (AP), posterior point (PP), leftmost point (LP), rightmost point (RP), supe-

rior point (SP), inferior point (IP) and midline of the brain must then be selected to determine the bounding hexahedron of the left and right hemispheres of the cerebrum (see Fig. 1). Although it is merely a problem of time for well-trained experts, determining AC and PC can be quite troublesome for most of the people without knowledge on brain anatomy. Besides, the selections can be difficult as the image quality varies even for the well-trained experts. There lies the necessity of computerized registration method.

2. PREVIOUS WORKS

The previously mentioned Talairach Grid System is defined on a human brain using AC-PC, VCA and midlines of the brain as guidelines. Because of the individual variations in height, length, and width of human brains, the measurements from these guidelines are only applicable to one individual. This becomes increasingly true with greater distance from the basal lines. Millimetric measurements, in fact, can only apply in a general population to the gray central nuclei, whose dimensional variations remain moderate. For this reason, the proportional grid system is proposed in three dimensions by Talairach and Tournoux [1]. This proportional localization system marks off the distances separating the basal lines and the cortical periphery defined by lines through SP, PP, IP, AP, LP and RP. This total volume is then divided as shown in Fig. 2. This division of the brain in unitary volumes is the road to a computerized atlas.

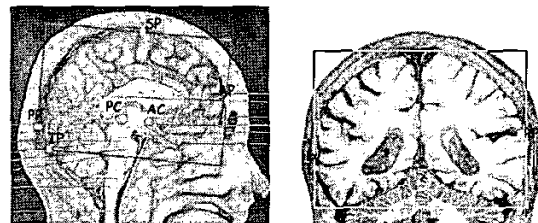


Fig. 1. Location of 8 points to define Talairach reference system.

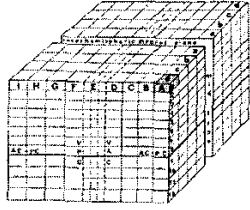


Fig. 2. The Talairach reference gridding.

3. PROPOSED ALGORITHM

In this paper, an automatic process of determining 10 necessary points is presented where the midsagittal plane is automatically extracted to find AC and PC using two-level shape matching of the corpus callosum in an edge-enhanced image. After AC and PC are found, remaining points are found using the intensity information of the cutview.

3.1. Finding Rotation Angle

The rotation angles should be found at first to extract the midsagittal plane that contains AC and PC. Therefore, axial and coronal rotation angles should be found as shown in Fig. 3.

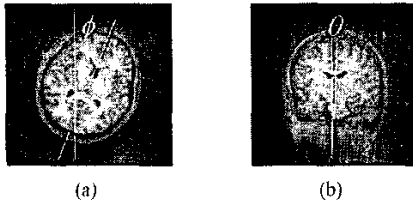


Fig. 3. (a) axial rotation angle, (b) coronal rotation angle.

In order to find the axial and coronal rotation angles, the symmetry property of left and right hemispheres of the brain is used. The idea is based on the fact that if a coronal or an axial image is projected onto a line that is perpendicular to the rotation angle, the projected data will show symmetry about the midline which has low intensity compared to the hemispheres in T1-weighted brain MR images.

The first step in finding the rotation angle is to find the center of symmetry for every candidate angle. The candidate angles are set to be $-8\pi/32, -7\pi/32, \dots, 7\pi/32, 8\pi/32$ for the first step search and $-3\pi/64, -2\pi/64, \dots, 2\pi/64, 3\pi/64$ around the result for the second step search in axial case. Since it is not likely that a bulk rotation occurs for coronal slices, the coronal search range is set to be half of the axial search range.

Any slice image is projected for every candidate angle

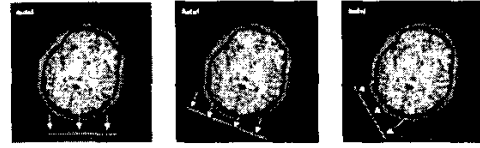


Fig. 4. Projection with different view angles.

as shown in Fig. 4 using eq. (1).

$$f_{\alpha}(u) = \sum_v \text{image}(u \cos \alpha - v \sin \alpha, u \sin \alpha + v \cos \alpha) \quad (1)$$

where $\text{image}(x, y)$ is the 2D axial image and $f_{\delta}(u)$ is the projected data with view angle of δ . u becomes the index of projected data. After the data is projected for every candidate angle δ , the center is calculated using eq. (2).

$$\text{center}_{\alpha} = \arg \min_u \sum_{i \in W} |f_{\alpha}(u - i) - f_{\alpha}(u + i)| \quad (2)$$

where the window size W is 50. Here, center_{δ} is the center point with which the projected data is symmetric. When the center is calculated, the difference between the projected data value at the center and the maximum peak of the projected data is calculated as in (3).

$$\text{diff}_{\alpha} = \max_u f_{\alpha}(u) - f_{\alpha}(\text{center}_{\alpha}) \quad (3)$$

The rotation angle ϕ is then chosen as in eq. (4).

$$\phi = \arg \max_{\alpha} \text{diff}_{\alpha} \quad (4)$$

This process is then repeated for smaller candidate angles as stated above. The rotation angle θ is also calculated in the coronal image in the same way as the axial image.

3.2. Finding AC and PC

After midsagittal plane is extracted using the rotation angles, AC and PC are located with help of shape matching. Before calculating correlation coefficients for shape matching, the midsagittal plane image is edge-enhanced. This is because the shape is usually a better attribute to differentiate two objects than the distribution of the gray level. Besides, to match against the shape of the template will provide a sharp peak of matching value contrary to the broad peak produced by the SAD method [2]. This attribute can be especially useful when the target image is MR image because MR images can be of various intensities. Hence, a matching method based on the distribution of the edges is used in finding AC and PC. Sobel convolution kernels are used here for

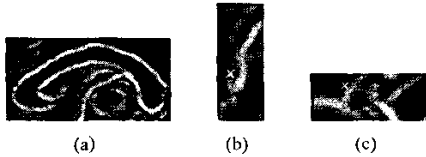


Fig. 5. (a) CC, (b) AC, and (c) PC templates for shape matching. Regions of x in (b) and (c) are AC and PC, respectively.

the edge-enhancement because they show good edge detection performance with relatively low noise sensitivity using simple kernels [3].

Once the target image is edge enhanced, edge enhanced Corpus Callosum (CC) template shown in Fig. 5 is used for the shape matching. Using CC template is appropriate because it is an easily distinguishable part of cerebrum and has small shape variance among different human brains. Although the corpus callosums of different humans are not exactly the same, a rough matching of CC can be a milestone of finding AC and PC which can be found near CC.

By calculating the correlation coefficients, the approximate point of the CC can be figured out. The next step is to rotate the template $+10^\circ$, $+9^\circ$, ..., -9° , -10° at the determined CC point from the previous match and calculate the correlation coefficient to find a better match. The result of CC template matching gives the potential target ranges for AC and PC in the next step. In order to accurately figure out AC and PC, AC and PC templates are used for further matching within the ranges. AC and PC templates are designed to satisfy the anatomical characteristics as shown in Fig. 5. These templates are also edge-enhanced and matched through the region determined by the CC match by calculating the correlation coefficients.

3.3. Detection of AP, PP, SP, LP and RP

After AC and PC selection, rest of the necessary points can be selected by inspecting cutview intensities. Here, the method will be explained mainly for AP because PP, SP, LP and RP can be found in the same way as AP.

For AP selection, the intensity along APC line is inspected for 10 slices above and 10 slices below APC line as shown in Fig. 6. When the intensity along the line is



Fig. 6. Slice selections for AP.

plotted, the intensity graph is first smoothed with gaussian filter to remove high frequency terms because they are likely to be noisy. When plotting the intensity, the first peak from left identifies with the skin of the brain and the valley following it is the skull and the cerebral fluid. The next part following the cerebral fluid with generally high average intensity is the cerebrum. Since AP is the anterior point of the cerebrum, the starting point of the cerebrum should be determined. In order to do that, the intensity of each pixel along APC line in midsagittal plane is added with the intensities of four neighbor pixels from other sagittal slices and the intensity sum is plotted. Here, the sum is taken instead of the intensity of just one pixel along the line to avoid the undesired effect due to noise. This plotting is repeated for 10 slices above and below APC line in axial slices. The idea here is simply to find the frontmost pixel of cerebrum. In order to do that, the intensity of 21 slices in total are gaussian fitted to determine the starting point. The valley is fitted to gaussian maximum and the part where cerebrum starts is fitted with gaussian curve. The starting point is then decided as the index where the intensity matches with half of the maximum gaussian value, i.e. the valley. After all 21 slices are gaussian fitted and the starting points are determined, the frontmost point is set as AP. The fitted result is shown in Fig. 7. Rest of the points are determined likewise.

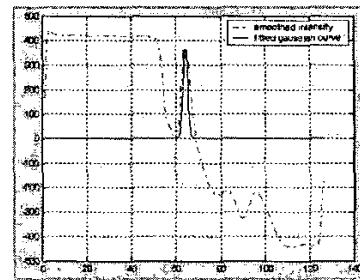


Fig. 7. Gaussian fitted result.

4. EXPERIMENTS

To verify the suggested automatic method, 10 datasets from Siemens 1.5T system and ISOL 3.0T system in KAIST Brain Science Research Center are used. The datasets are acquired with T1 weight and have a dimension of $256 \times 256 \times 256$ with resolution of $1mm^3$. Two of the datasets are acquired with axial rotation angle of more than 20° . Fig. 8 shows the projected data for determining the rotation angle. The graph shows that the intensity near the longitudinal fissure has a local valley. This tendency is the strongest when the candidate angle is in accordance with the actual rotation angle. As shown in Fig. 8, the maximum difference of the actual rotation angle has the largest difference among the



Fig. 8. (a) projected data with different rotation angles
(b) Maximum differences of peak to center

values from all candidate angles. Fig. 9 shows 1st and 2nd shape matched results with original edge enhanced images of the midsagittal plane extracted from the method stated above. These images show that the positions of AC and PC are accurately found with stability. As far as the boundary points are concerned, finding the boundaries are not difficult even with manual selections when the images are not rotated. However, when the image is rotated, the boundaries cannot be accurately found manually because the image shown in 2D screen is inevitably inaccurate as shown in Fig. 10. The final registration result is shown in Fig. 11. The 3D brain MR image can then be deformed according to the result using affine transformation.



Fig. 9. Matched result.

5. CONCLUSION

The proposed method shows that the Talairach-based registration of brain MR images can be performed automatically

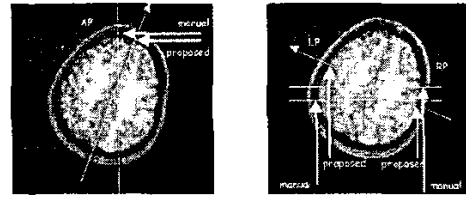


Fig. 10. Boundary comparison.

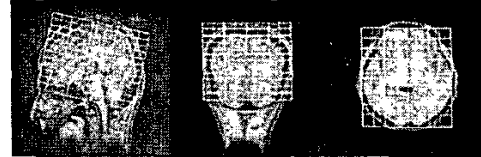


Fig. 11. Registration result.

using the anatomical information and natural characteristics of the brain MR images. It first extracts the midsagittal plane from 3D brain MR images by finding rotation angles using the symmetry of the intensity across brain hemispheres. It then selects AC and PC using two-level shape matching in the edge-enhanced midsagittal plane and further selects the boundary points (AP, PP, SP, LP and RP) using the unique contrast information of brain MR images. The proposed method can be especially effective when applied to images with bulk rotation because it assures more stable results than manual registration.

6. ACKNOWLEDGEMENT

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7. REFERENCES

- [1] J. Talairach and P. Tournoux, Co-planar stereotaxic atlas of the human brain, Thieme Medical Publishers, 1988.
- [2] R. runelli and T. Poggio, Template Matching: Matched Filter and Beyond, Pattern Recognition, Vol.30, No.5, pp.751-768, 1997.
- [3] I.Pitas, Digital Image Processing Algorithms and Applications, New York, Wiley-Interscience, 2000.
- [4] A. Lundervold, N. Duta, T. Taxt, A. Jain, Model-guided Segmentation of Corpus Callosum in MR Images, IEEE Computer Society Conference on Computer Vision and Pattern Recognition, vol.1, pp.231-237, Colorado, 1999.