Midsagittal surface extracted from the midsagittal plane using image foresting transform

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Abstract

The region between the cerebral hemispheres is an important area to locate. Both structures and the area itself is used for spatial normalization. Interhemispheric structures are also correlated with various diseases. The hemispheres are partially separated by the interhemispheric fissure. Although the fissure commonly has a slight curvature, it is often approximated with the midsagittal plane. The solution is often satisfactory when for instance the anterior and posterior commissures needs to be located for spatial normalization, but sometimes a more accurate solution is needed. Here, a method that extends a midsagittal plane into a midsagittal surface is introduced. The plane approximation is used for initialization of the Image Foresting Transform that divides the brain into two halves based on voxel neighbor similarity. Experiments revealed that the Image Foresting Transform gives a more accurate separation of the cerebral hemispheres in the interhemispheric fissure, but is less reliable in homogeneous areas such as corpus callosum. The surface is calculated in 6 seconds and with their different strengths, the plane and surface might be used in combination to obtain the most information concerning the interhemispheric area.

Keywords: midsagittal surface, midsagittal plane, image foresting transform

1. Introduction

The interhemispheric fissure of the human cerebrum is often approximated with a midsagittal plane (MSP). The MSP often gives satisfactory information, but for cases where such a crude approximation of the fissure is not enough a midsagittal surface (MSS) is needed.

Transformation into Talairach coordinates (Talairach and Tournoux, 1988), is a common procedure in brain processing. An assumption when transforming the brain into Talairach space is that the hemispheres are symmetrical. These coordinates are defined using the MSP, and no clear definition using a MSS is, to the authors knowledge, defined. To reduce the effect of lateral asymmetry it might be of use to compensate for the fissures curvature using the MSS in a preprocessing step.

Interhemispheric structures, such as the anterior and posterior commissure which are two structures used to define Talairach coordinates, could be more easily found using a MSS. If the interhemispheric fissure has high curvature the MSP might not contain cross sections of these commissures. The extracted MSS is less sensitive to curvature and should be more likely to contain the commisures in such cases.

MSP methods have been validated with good results in the past (Hu and Nowinski, 2003), and by using knowledge from the MSP an optimization method could be used to find the MSS. This paper explores the possibilities of using the image foresting transform (IFT, Falcao et al. (2004)), initialized by the MSP, to calculate the MSS.

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2. Materials and methods

Using the MSP, foreground and background seeds are placed automatically and are used as input for the IFT algorithm. This produces a segmentation of the image and the cutting plane of the segmentation is interpreted as the MSS.

2.1. Midsagittal plane

A midsagittal plane is often located by finding the plane giving either the maximum global lateral symmetry, or by using a local symmetry measure of the surrounding area of the plane. In this paper a method introduced by Hu and Nowinski (2003) is used for spatial knowledge when automatically placing seeds for the IFT (2.2.1). This method calculates a local lateral similarity around a line in 2D. By varying the lines rotation and lateral offset, the most locally symmetrical line is located. This is done for all axial 2D slices in the brain. Lines considered as outliers are removed, and the MSP is the plane that best fits the remaining lines.

2.2. Image foresting transform

The image foresting transform is a graph based segmentation method that finds the shortest path from each voxel to a seed. By assigning different labels to the seeds and propagating the label along the shortest path, a voxel will be assigned the same label as the closest seed and the image can be segmented. The length of a path π is determined by a cost function f. If there is no path x with the same origin and destination as π resulting in $f(x) < f(\pi)$, then π is the shortest path between its origin and destination.

2.2.1. Seeds

In order to separate a brain along the interhemispheric fissure, seeds need to be placed in each hemisphere with each hemisphere giving its seeds a unique label. A MSP is, if the conditions for the extraction method used are met, located in the region of the true interhemispheric fissure. By using this assumption, seeds placed on different sides of the MSP should correspond to different hemispheres. The distance between the MSP and the placed seeds should be determined by mainly two factors: how much the curvature of the fissure is expected to be and the expected performance of the MSP extraction method.

2.2.2. Path cost

A gradient value for voxel v was created from the input intensity image I as

$$Grad(v) = \frac{1}{n}\sum_{i=1}^{n}|I(i) - I(v)| \tag{1}$$

where $I(i)$ is the i:th neighbors intensity, and $n = 26$ for 26-adjacency.

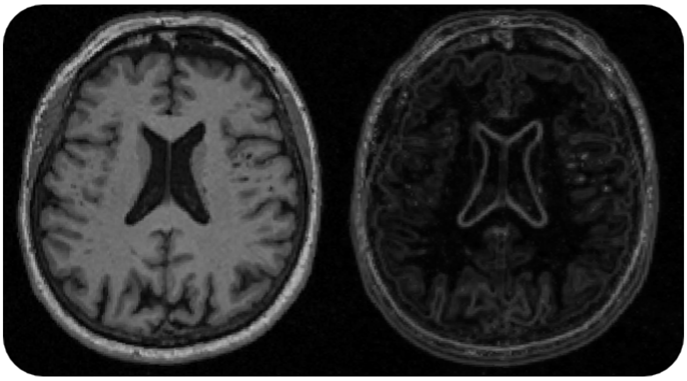

Figure 1: **Example of gradient image.** To the left is the original intensity image. To the right is a gradient image created as in Eq. 1 with 26-adjacency.

The path cost for path π can then be defined as

$$f(\pi) = \sum_{i=1}^{k} Grad(i) \tag{2}$$

where i is the current voxel being included in π.

All paths start growing from the seeds, having initial cost $f(seed) = 0$, and can grow in 26 directions. Paths moving in areas that are homogeneous in I expands at a low cost, while paths crossing intensity boundaries get a high path cost. This makes it more likely that the image becomes separated in areas with large intensity variations.

2.3. Experiment

To investigate the proposed improvement of the MSP, the extracted MSS was visually compared to the original MSP by an experienced operator.

2.3.1. Images

The images used in the experiments were sagittal T1-weighted magnetic resonance images with a size of 256x256x170 voxels. In-plane resolution was 0.94x0.94 mm, with a slice thickness of 1.2 mm. A total of 10 images were processed.

2.3.2. Seeds

Seeds were placed as planes parallel to the MSP. Since the experimental data had rather straight interhemispheric fissures and the performance of the MSP method is considered good, the seeds were placed only 9.4 mm from the MSP. Since the seeds were placed as solid planes, no shortest path from a voxel to the seeds on the opposite side can exist. Therefore no voxels outside the seed planes were calculated, as they could be prelabeled with the label from the closest seed plane.

3. Experimental results

Overall the MSS followed the interhemispheric fissure more accurately than the MSP, with only a few mislabeled voxels. However, in homogeneous areas such as Corpus Callosum the MSS was less accurate (Fig. 2).

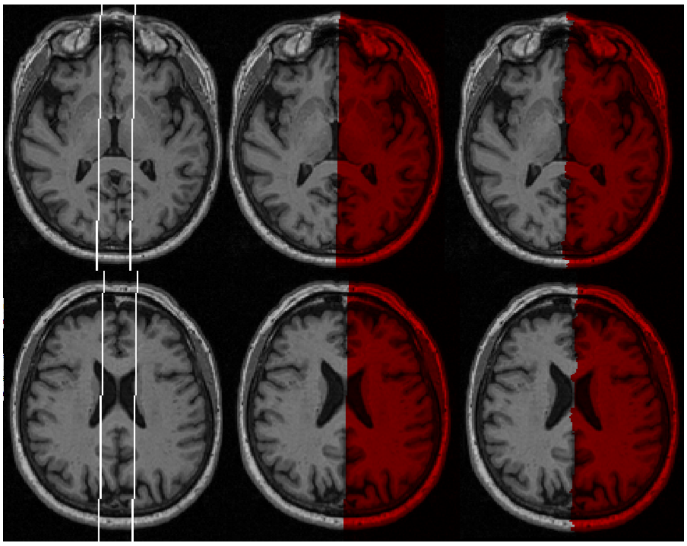

Figure 2: **Example of separation.** The left column shows the input image with automatically placed seeds. The middle columns shows the midsagittal plane separation. The right column show the separation with the midsagittal surface.

The MSP was calculated in approximately 2 seconds and the IFT calculation took approximately 6 seconds using a binary heap priority queue.

4. Discussion

The possibility of using IFT to expand an MSP to follow the interhemispheric fissure has been examined. The interhemispheric fissure is more accurately followed, but homogeneous areas are not accurately divided with IFT. With running times of 2 seconds for MSP and an added 6 second for MSS, both solutions are time efficient.

Completely homogeneous areas will add zero to the path cost. This is however rarely the case in MRI as it is subject to noise. This noise makes the separation appear jagged and a bit random. To avoid this the intensity image could be smoothed. This comes at a cost of reduced gradient information at weak intensity boundaries and was not performed in the conducted experiments.

A common problem when separating the cerebral hemispheres is that the boundary between the lateral ventricles (septum pellucidum) is brighter than the surrounding areas, while the rest of the desired boundary is either darker or homogeneous compared to the surroundings. By using IFT with a gradient based path cost, this problem is eliminated. It is however crucial that both lateral ventricles contain seeds from their respective hemisphere. The septum pellucidum-ventricle boundary is generally weaker than the tissue-ventricle boundary. If only one ventricle contains seeds it is probable that both ventricles would be assigned the same label.

5. Conclusion

In this paper it has been investigated if a midsagittal plane could be used to find a midsagittal surface with the image foresting transform. The weakness of the midsagittal plane not being able to follow curved interhemispheric fissures is lessened with the surface. However, the surface has difficulties in separating homogeneous regions such as corpus callosum. The midsagittal surface, as calculated in the experiments, is extracted in approximately 6 seconds on a standard computer. Since plane and surface has different strength and uses both could be extracted and a combination of their respective information could be used.

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