Automatic Cerebellum Skeleton Extraction In Human MR Brain Images

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Introduction

Image skeletons have been widely used in recognition and representation of objects, and analysis of medical data. In this project we developed an automatic algorithm for extraction of the white matter skeleton of human cerebellum (CB) based on the ordered region growing (ORG) method [1] and scale-space theory [2].

Methods

Data Acquisition Coronal MRI brain images covering the whole CB were collected using a 1.5 T Siemens Vision scanner and 3-D Turbo FLASH imaging sequence. TR/TE = 11.4/4.4 ms, flip angle = 10°, slice thickness = 2 mm, in-plane resolution = 1 x 1 mm^2.

Algorithm The procedures of the algorithm are as follows: **(1)** CB images were segmented out from the collected head images, resampled and standardized (matrix size = 128 x 64, pixel size = 1 x 1 mm^2, slice thickness = 1 mm). **(2)** The images were preprocessed to improve the contrast using a Gaussian-type histogram equalization method. **(3)** Medialness images [3] (*M*, or multiscale responses) were obtained from convolution of the original images (*I*) with a normalized Laplacian-of-Gaussian (LoG) operator (*K*) at a discrete set of scales (σ = 1, 2, 3, 4, 5) (Fig. 1):

$$M(x,y,z,\sigma) = K(x,y,z,\sigma) * I(x,y,z);$$

$$K(x,y,z,\sigma) = -\sigma^2 (G_{xx} + G_{yy} + G_{zz}); \quad G(x,y,z,\sigma) = \frac{1}{\left(\sigma\sqrt{2\pi}\right)^3} e^{-\frac{x^2+y^2+z^2}{2\sigma^2}}$$

(4) For each image voxel, the maximum response (i.e., maximal *M* value) and the corresponding scale σ_{max} were found (Fig. 1). The maximum response images were created. **(5)** ORG acyclic graphs were generated on the maximum response images. Starting from the seed point, which was automatically set at a voxel belonging to CB, the ORG graphs grew to the neighboring points that had the highest voxel values; and this procedure was performed iteratively. Fig. 2 illustrates the algorithm in 2D situation. Fig. 3 shows the result from the ORG on a sample CB slice. **(6)** Curvature images were generated by applying a corner detector $I_{vv} I_w^2$ on the maximum response images. The corner detector was defined in a local gradient-based coordinate system (v, w), where I_w was the magnitude of the local gradient, I_{vv} was the second-order derivative in the direction perpendicular to the local gradient. Voxels with local maximum curvatures were chosen as end points of the skeleton branches. **(7)** CB skeleton was obtained by tracing back from the end points to the seed point according to ORG graph connectivity. **(8)** CB skeleton was refined by eliminating branches of lengths smaller than a specified minimum length (MIN = 3 voxels).

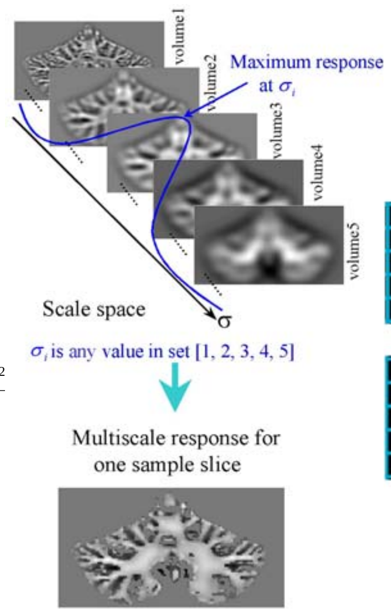

Fig. 1: Illustration of multiscale response calculation.

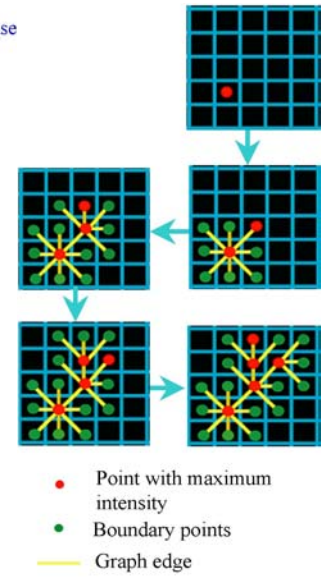

Fig. 2: Illustration of ordered region growing in 2-D case.

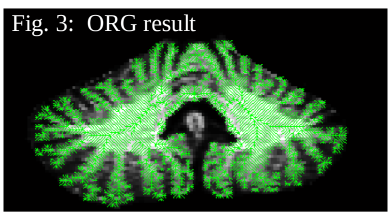

Fig. 3: ORG result

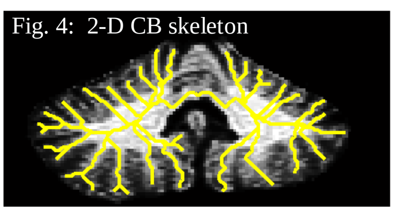

Fig. 4: 2-D CB skeleton

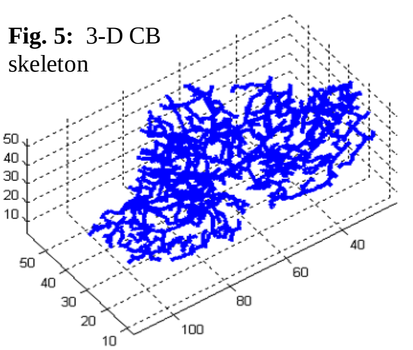

Fig. 5: 3-D CB skeleton

Results

The resultant CB white matter skeleton is shown in a 2D sample slice (Fig. 4) and in 3-dimensions (Fig. 5).

Conclusions & Discussion

1. The results indicate that the skeletons obtained using the developed algorithm accurately represent the skeletal structure of CB white matter.

2. This method can yield both 2D and 3D image skeletons. The generated skeletons are graphs, with all of the voxels connected. The algorithm can yield skeletons directly from gray-scale images, avoiding errors introduced from auxiliary processing procedures such as removal of unwanted tissues in the CB images.

3. The skeletons in graph format are easier to parameterize than those in image format, thus making it more convenient for characterizing the structure of interest, for example, measuring lengths and widths of the branches, determining fractal dimensions of the structures [4], etc.

References

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