Segmentation of the Structure of the Mouse Spinal Cord on DTI images

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Introduction

Diffusion Tensor Imaging (DTI) provides important information on the integrity of the tissue structure and the technique is nowadays widely used to characterize the spinal cord (SC) pathologies. To describe the potential alteration/regeneration consequent to the disease, the DTI metrics have to be studied in particular region of interest, generally manually divided into ventral and dorso-lateral gray matter and ventral, lateral and dorsal white matter

In this abstract, a fully automated method is proposed to segment the sub-structures of the mouse SC. Such automated segmentation is of great importance as it removes a tedious part during the analysis of the data as well as the intra/inter operator variations of manual segmentation.

Method

In this abstract is proposed a method to delineate the sub-structures of mice SC in a fully automated way. For the proposed method,SC WM/GM segmentation is a required input which can be obtained with the method described in [2]. On output, the GM substructures were distributed in Left Ventral and Dorsal GM and Right ventral and dorsal GM whereas substructures of WM were distributed into Left Lateral WM, Right Lateral WM, Ventral WM and Dorsal WM.

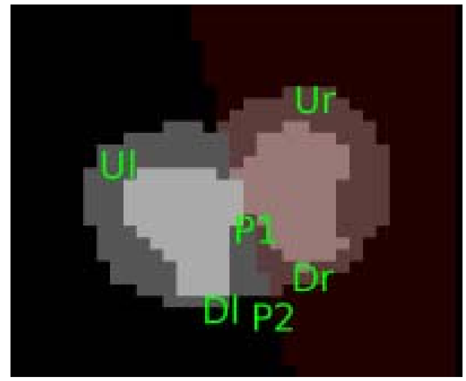

Figure1: Points used to define the substructure of the WM and GM tissues

Left/Right Segmentation: The SC is divided into its left and right side by searching the best symmetry axis on the input WM/GM segmentation image. Axes in the plane are parameterized by the angle θ between their normal and the x axis, and the distance α to the centre of mass of the SC mask. To measure the symmetry of the SC with respect to an axis, the sum of square difference between the SC image and its symmetric is computed. The Left/Right (L/R) axis is chosen as the axis achieving the best symmetry.

GM Ventral/Dorsal Segmentation: The GM is split into Ventral and Dorsal GM by a line orthogonal to the L/R axis. This line passes by the P1 point (see Fig XXX) defined as the first point on the L/R axis after the GM by going through the image along the ventral/dorsal direction (v/d).

Lateral WM segmentation: To discriminate sub-structures of WM, the first point on the L/R axis after the SC mask is found (P2 on Fig XXX) (by going through the v/d direction). In the right part of the SC, the Ur point, the point of the WM/GM border the furthest from P2, is then used to discriminate Lateral WM from Ventral WM. The Dr point, defined as the point of the WM/GM border the furthest from Ur is used to discriminate Lateral from dorsal WM. Similar operations are then performed on the left part of the SC.

Results

The algorithm was run on the DTI images of 10 mice (7 slices each). The images were acquired on a 11.75T Bruker MR system (see [3] for details). An example of the segmentation procedure is shown on Fig 2. The segmentation procedure was first evaluated by visual assessment of two experts. Slices were classified in three categories according to their segmentation results: C1 for accurate results (<5 pixels mismatch), C2 when few pixels (<10 pixels) were misclassified and C3 when a gross error was visible. Results in percent of the total number of tested slice are given in Table I. For the WM/GM segmentation, the method described in [2] has been used. For the sake of completeness, results of the SC mask and the WM/GM segmentation provided by this method are also reported. Table I shows that more than 40% of the slices were classified as accurate by the two experts and gross error were present in only 18% of the slices. One can note the degradation of the results along the process (SC mask segmentation, WM/GM segmentation and structures delineation). This entails that any improvement on the WM/GM segmentation will conduct to improvement of the structures segmentation.

Table I: Results in percent of the visual assessment evaluation

	SC mask			WM/GM			Structures		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
Exp1	88	8	4	54	38	8	45	37	18
Exp2	75	23	2	58	25	15	42	40	18

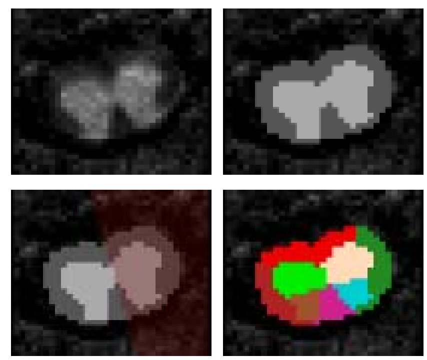

Figure 2 : DWI, WM/GM segmentation, Left/Right axis, final results

The agreement between the experts and the automated segmentation was evaluated by measuring the intra-class correlation (ICC) (see [4]) of the mean λ_1 in ROI manually drawn by the experts or by the automatic method. To account for partial volume effect, the ROI are manually drawn inside a given structure and the regions produced by the automatic segmentation are eroded before computing the mean value. ICC of all the ROI, using 11 slices chosen in the C1 category of the visual assessment are reported in Table II. This table shows that the automatic procedure presents better agreement with the experts in the ventral part of the GM than the dorsal GM. The results are also satisfactory for the WM structures. One can note that the agreement is better with Exp2 than with Exp1 but one some structures, the two experts present a poor ICC.

Table II: Intra-class Correlation on λ_1 images

	Exp1/Exp2	Exp1/Auto	Exp2/Auto
L Ventral GM	0.84	0.94	0.90
L Dorsal GM	0.90	0.67	0.59
R Ventral GM	0.74	0.87	0.79
R Dorsal GM	0.99	0.54	0.49
L Lateral WM	0.17	0.34	0.50
Ventral WM	0.01	0.07	0.90
R Lateral WM	0.61	0.76	0.83
Dorsal WM	0.93	0.86	0.88

Conclusion:

In this work, has been presented a method to segment the substructure of the SC of a mouse given its WM/GM segmentation. Together with [2], this creates a fully automated procedure to segment these structures from DTI images of the mouse SC. The proposed method seems to be very promising and should offer a huge gain of analysis postprocessing time.

References:

[1] Budde MD*, et al.* Magn Reson Med 2007;57(4):688-695. [2] Sdika M, *et al* A Fully Automated White Matter / Gray Matter Segmentation of Mice Spinal Cord on DTI Images, submitted to ISMRM 2010. [3] Callot V, *et al*. NMR Biomed. 2008 Oct;21(8):868-77. [4] Fisher R, Statistical Methods for Research Workers.