Classification of Thalamic Nuclei in High Resolution Ex Vivo Imaging

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Introduction

With the advent ultra-high field strength MRI scanners, it is now possible to image deep-brain structures at sub-millimeter resolutions. The goal of this work is to assess the feasibility of thalamic nuclei delineation in *ex vivo* brain tissue. Two methods of classification are compared: an intensity-based method that uses a Fisher linear discriminant and an edge-detection method based on the Canny method to detect local maxima.

Methods

A human *ex vivo* hemisphere was scanned on a 7T Siemens system using an end-capped TEM head coil. After having been fixed previously for several months, the brain was then placed inside a bag and formalin was added under vacuum to eliminate air bubbles from the sulci. A gradient-recalled echo sequence was used with a TR of 30 ms, TE of 3.06 ms, and flip angle of 10 degrees. Previous work [1] has observed the relaxation parameters of brain tissue to decrease with fixation duration, but to become constant after 11 weeks. The image displayed in Figure 1 is proton-density weighted and has been processed to remove low spatial frequency RF reception inhomogeneities. The field-of-view chosen was 154x154 mm^2, with a matrix size of 512x512 and a slice thickness of 0.3 mm, yielding an isotropic resolution of 300 microns after an hour-long scan.

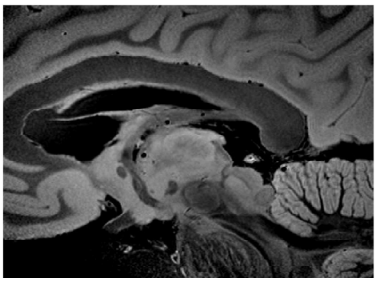

Figure 1: GRE *ex vivo* image through the midbrain. 300 micron isotropic resolution

Guided by an atlas [2], regions of interest were selected manually to encompass parts of each of the following thalamic nuclei: anterolateral (AL), dorsomedial (DMN), lateral dorsal (LDN), and pulvinar (PUL). The Fisher linear discriminant (FLD) is defined as the linear transformation that maximizes the separation between two subsets relative to their within-class scatter [3]. The FLD was computed for each pair of nuclei using the means and variances of each ROI. An intensity threshold was then found to distinguish between nuclei and misclassification rates determined for separately-defined ROI's.

The results were compared to a Canny method of edge detection. This method finds edges by determining the local maxima of the gradient of the image, which is found via the derivative of a Gaussian filter. This method is less sensitive to noise in the image because a separate threshold is used to detect strong and weak edges. Furthermore, weak edges are only reported if connected to strong edges.

Results and Discussion

The effectiveness of the FLD threshold varied between nuclear pairs. All scaled intensities are plotted in Figure 2, with the percentage misclassification listed. Thresholds between AN and PUL and PUL and DMN resulted in no misclassifications; between LDN and DMN, 6.53% error; between AN and LDN or LDN and PUL had errors near 30%; between AN and DMN, 65.2% error. The FLD is only optimal when the classes are Gaussian distributed with the same covariance structure.

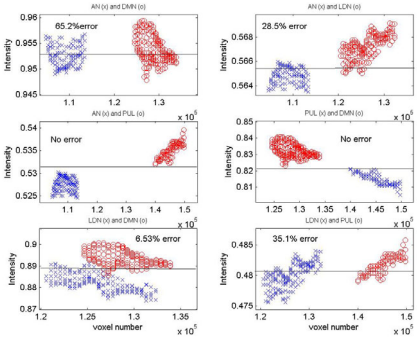

Figure 2: Scatter plots of thalamic nuclei pairs using FLD to determine a threshold for classification. Misclassification rates are listed.

The Canny edge detection resulted in clearer distinctions between nuclei, as shown in Figure 3. The AN, LDN, and PUL are well demarcated; the borders of the DMN are less distinct, and the posterior-most border is not visible. The presence of two other nuclei, the ventrolateral (VL) and the centromedian (CM) are also suggested by contour lines. This method of nuclear delineation was most likely more successful because it utilized the large change in intensity due to the internal medullary lamina that separates nuclei.

Conclusion

These preliminary results show that delineation of thalamic nuclei is possible in 300 micron *ex vivo* resolution images when edge detection is used. The FLD method is promising and may achieve a lower misclassification rate when used with higher-dimension data sets, which will be compiled from multiple runs with various parameters to optimize contrast for detection.

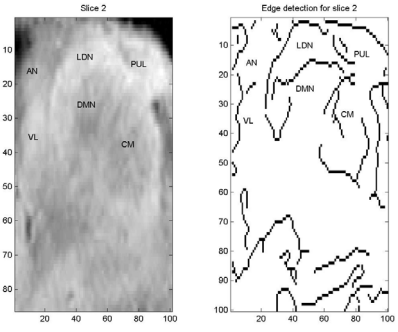

Figure 3: Six thalamic nuclei are discernable in a zoomed MR image (left) by using Canny edge detection (right).

References

[1] Tovi M and Ericsson A, *Acta Radiol.* 33(1992):400-404.

[2] DeArmond, SJ, Fusco, MM, and Dewey MM *Structure of the Human Brain*

[3] Duda, RO and Hart, PE *Pattern Classification and Scene Analysis*