Hippocampal surface dentation characteristics through sub-pixel segmentation

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Purpose

The convoluted structure of the cerebral cortical surface has drawn researchers' attentions in the past decade and correlations with many psychological and/or psychiatric disorders have been established. Sub-cortically, the hippocampus is a structure also possessing rich surface and shape features with considerable morphologic variability between individuals. The under-surface of the hippocampus has a dentated or "tooth-like" appearance, as seen in the sagittal plane. The degree of dentation varies between normal individuals from prominently dentated (Figure 1C) to minimally dentated (Figure 1G). Unfortunately, due to the small size of these features being on the border of common 3D imaging resolution, these features are difficult to characterize. To the best of our knowledge, there has been no previous analysis on this specific hippocampal shape characteristic. In this work we present a segmentation scheme utilizing sub-voxel precision for the hippocampal dentation structure extraction from 3T MR images.

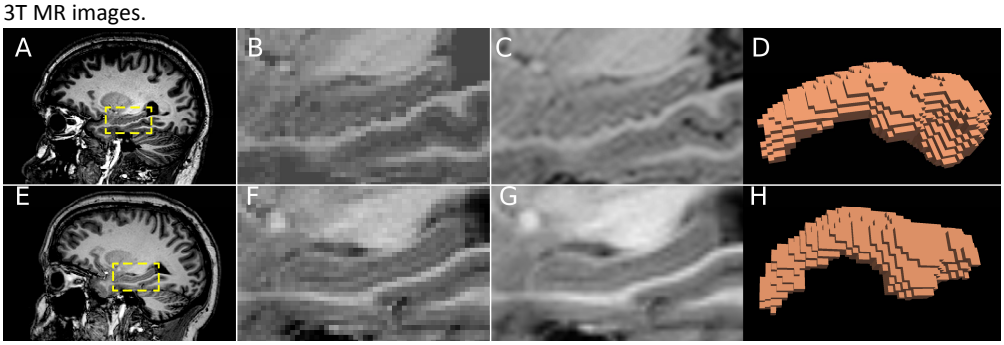

Figure 1. **Top row**: a prominently dentated hippocampus. **Bottom row**: a minimally dentated hippocampus. **(A),(E)**.Full sagittal images through the hippocampus. **(B),(F)**. Magnified view of hippocampal region in original image resolution of 1 mm x 1 mm. The undulating hippocampal contour in B is difficult to appreciate in the native resolution. **(C), (G)**. Hippocampal region in sub-pixel resolution (0.1 mm x 0.1 mm). The bumpy contour of the inferior hippocampal surface can be clearly seen in C as opposed to the smooth contour in G. **(D)**, **(H)** Reconstructed surface at the native resolution, the dentation information is lost.

Methods

We first segment the hippocampus under the native image resolution (1.0x1.0x1.5mm^3). To that end, a training set of 20 T1 MPRAGE MR images are obtained with hippocampus manually traced out. Given a new image I at similar resolution, the method in[1] computes a probability map P at the native resolution, which indicates the hippocampal region with high values. Next, the sub-pixel segmentation is carried out. Specifically, the I and P are up-sampled to an isotropic resolution at 0.1mm using the Lanczos kernel. The smoothing on the edges is addressed by a few iterations of the anisotropic diffusion[2], which gives J and Q (for I and P, resp.) at higher resolution. Subsequently, the segmentation is fine-tuned at high resolution to clearly delineate the dentated inferior hippocampal surface. To that end, the robust statistics segmenter[3] is used. In particular, the hippocampus intensity feature can be learned from the high-probability regions in Q while the low-probability regions naturally provide a "rejection region" that prevents the evolving surface from growing inappropriately when extracting the hippocampus. In addition, the learned hippocampus shape information from the training sets provides an admissible space which also regularizes the segmentation[1]. This finally provides the segmentation of hippocampus in the high resolution.

Results

The capability of extracting detailed hippocampal structure is demonstrated in Figure 2.

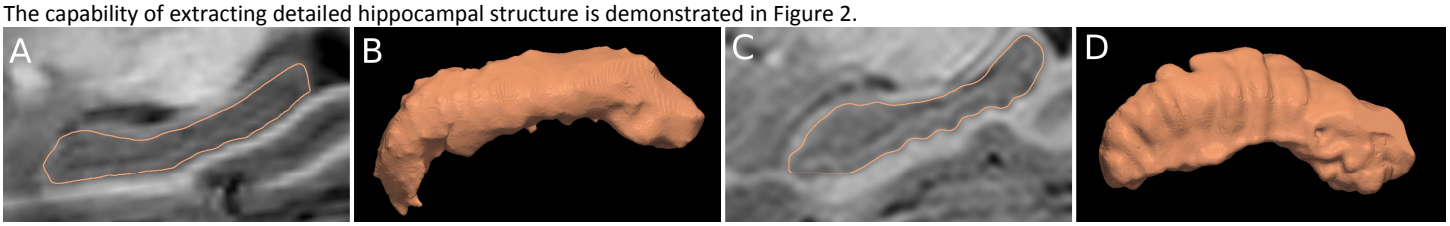

Figure 2. Hippocampus with *smooth* inferior surface in **(A)** sagittal view and **(B)** 3D surface, inferior view. Hippocampus with *bumpy* inferior surface in **(C)** sagittal slice and **(D)** 3D surface, inferior view. The ridges that produce the dentated appearance of the hippocampus can be clearly seen in D and are notably absent in B. Comparing B/D with Figure 1H/1D the improvement can be seen.

Conclusion and Discussion

We present a sub-pixel segmentation scheme for the hippocampus that is tailored to reveal subtle surface features unique to the hippocampus. This enables delineation of surface features that are often overlooked and not well depicted with segmentation performed entirely in the native resolution. This analysis was based on a sequence commonly collected in clinical and research protocols. This opens up possibilities of future research in hippocampal surface analysis correlating the degree of dentation with a range of diseases including epilepsy, Alzheimers disease, and schizophrenia.

References

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