HippoQuant: Combining Geometrical and Intensity Information for 3D Hippocampus Detection in 3D T1-weighted MRI images

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Introduction

A number of MRI studies have shown the significant role of hippocampus in patients with Alzheimer's disease [1]. Furthermore, longitudinal studies suggest that hippocampal volume loss predicts cognitive decline. The hippocampus is a small gray matter (GM) structure that is adjacent to other GM structures (e.g. amygdala, para-hippocampal gyrus). This feature of the hippocampus means that in magnetic resonance (MR) brain images, the hippocampus has relatively low contrast and indistinct boundaries along significant portions of its surface. In this context, hippocampus detection using semi-automatic or automatic approaches is challenging, particularly in multi-centers clinical studies. In this work, we propose a new, fast, semi-automatic hippocampus segmentation procedure based on user-defined landmarks. This approach combines both geometrical and statistical information, leading to potentially dramatic reductions in rater time and interaction, greater reliability, and a technique that is insensitive to variations in hippocampal size and shape, - all important considerations for application in multi-centers studies.

Method

We present *HippoQuant*, a semi-automatic segmentation method for hippocampal delineation in 3D T1-weigthed MRI images. *HippoQuant* is composed of three main steps. The main inputs are the MR volume to process and a 3D discrete Hippocampus surface model (triangle mesh), obtained by manual contouring effected by an expert rater on a single subject. User interaction is required only in the first step of HippoQuant, a landmark setting process, which takes five minutes per patient, for both left and right hippocampi. About 80 landmarks per hippocampus are marked using both sagittal and coronal views to cover the external hippocampus boundary. The second step consists of the geometric deformation of the 3D hippocampus surface model to match these user-defined landmarks. First, the well-known Iterative Closest Point (ICP) rigid transform is applied [3], which matches each vertex in one surface with the closest surface point on the other, and then applies the transformation that best matches one surface to the other using a least squares approach. The ICP transform is then supplemented by a Thin Plate Spline (TPS) transform [4] which describes a nonlinear warp defined by a set of source (3D surface points resulting from the ICP transform) and target landmarks (user-defined landmarks). This second step leads to a "binary mask". In parallel, the 3D MR image is segmented into 3 tissue classes (WM, GM and CSF) [5] to identify CSF or CSF-like structures (uncal sulcus and "black holes") located within the hippocampus. The output is a "presegmentation mask". In the final step, these masks are merged to generate a hippocampal mask. This novel approach combines both morphological information and tissue class segmentation (based on intensity information).

Results

HippoQuant performance was evaluated on 20 patients, chosen to emulate the full range of hippocampal size and shape encountered, and to test performance in scans from different clinical centers. Images were acquired at 1.5T and 3T using a 3D T1-weighted MPRAGE sequence. For each patient, both manual contouring (**1h per patient**) and landmarks setting (**5 min per patient**) were performed by a single expert. *HippoQuant* results are quantitatively compared to manually defined gold standard by computing the overlap measure (Ov) and the relative volume error (RV). As shown in Table 1, a mean Ov of 92.4% (92.2%) and a mean RV of 5.3% (4.6%) are achieved for left and right hippocampi, respectively, illustrating segmentation accuracy with a considerably reduced user interaction time. An illustration of the hippocampus detection pipeline is given by Figure 1. On the sagittal view (Figure 1-a), which shows a CSF-like "black hole", landmarks are set by the user. The presegmentation mask is given by Figure 1-b and the hippocampus mask is illustrated by Figure 1-c. A 3D view including left and right hippocampi is shown in Figure 1-d.

Conclusion

We put forward a new technique, *HippoQuant*, which combines both morphological detection of the hippocampal boundaries and tissue segmentation. The hippocampal surface is defined by a combination of user-defined landmarks and an *a priori* surface model. The use of a limited number of landmarks leads to a dramatic (over 90%) reduction of rater time. These initials results suggest that *HippoQuant* is reliable, accurate compared with the existing gold standard [5], robust to data of different quality and to variations in hippocampal size and shapes and is well-suited to clinical studies. A deeper clinical validation is in progress.

References

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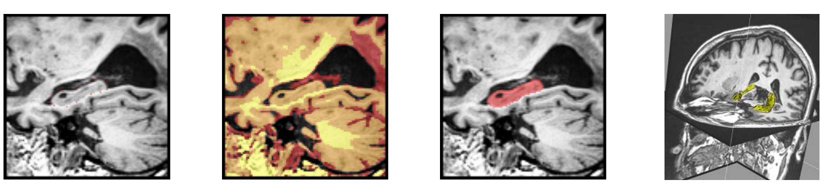

a) b) c) d)

Figure 1: *HippoQuant,* a) landmarks setting, b) presegmentation mask, c) hippocampus mask and d) 3D display of detected hippocampi

	Left Hippocampus	Right hippocampus
Ov	92,4 %	92,2 %
RV	5,3 %	4,6 %

Table 1: Results comparison using manual contouring and *HippoQuant*