# Efficient Atlas-based Analysis of the Hippocampus

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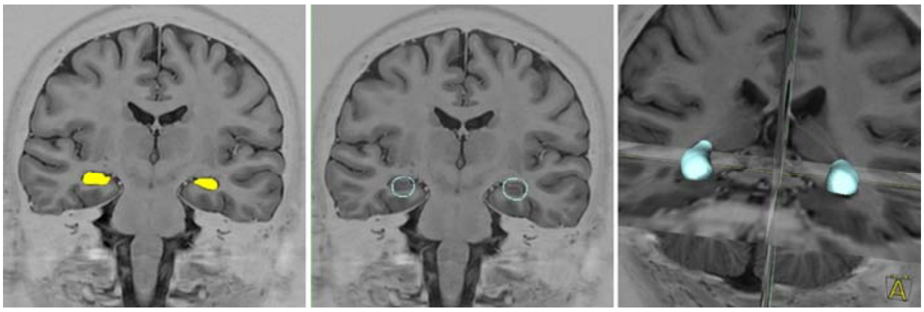
**Abstract.** Volumetric approaches for the analysis of hippocampal structures (HS) are required for the diagnosis of different diseases. In order to diagnose, evaluate and compare patient datasets, standardized and reproducible analysis supports physicians in clinical routine and research. In this paper, we present a practical application for volumetry in MR volume datasets. The approach combines the semiautomatic linear registration of an atlas based polygonal model with T1-weighted (based on inversion recovery protocol) and T2-weighted MR images and the automatic volumetric assessment of diseased structures. The approach was evaluated and compared with manually segmented MR datasets.

## 1 Introduction

MR-volumetric assessment of temporomesial structures, especially hippocampal structures, play an important role in the diagnosis of temporal lobe epilepsy, degenerative diseases like Alzheimer dementia and the evaluation of their course of disease. Objective, reliable and reproducible semi- or fully automatic methods are required to record minor atrophies, evaluate chronological changes and confidently compare them among different observers and institutes. Resulting increased inter- and intra-observer variability of manual techniques limit the role of segmentation in clinical studies. Only valid results of hippocampal volume segmentation can be confidently correlated to severity of disease progression and to neurohistopathological results.

Conventionally used manual segmentation is a time consuming procedure, which therefore cannot be performed in clinical routine. Fully automatic segmentation, like in [1], often fails if the hippocampus is relatively small and the shape of the object is highly variable. Compared to this, semiautomatic methods, like in [2], may provide a more realistic approach because of the combination of human expertise and automatic techniques. In [3] a model which contains a triangulated surface and the corresponding gray scale volume is used. This requires a presegmentation of the objects of interest for reconstructing the surface. In [4] a deformable model is generated from a single manually labeled volume

**Fig. 1.** Alignment of the atlas after transformation to the volume coordinate system: For comparison the hippocampus was segmented manually by voxel painting in one coronal slice (left). 2D representation of the volume, including the corresponding intersections of the atlas with the volume, using atlas transformation (middle). A 3D visualization, which serves for spatial orientation, is shown. (right)



to measure the size and the shape of the hippocampus. The disadvantage of this approach is the manual segmentation task of the hippocampus and the low resolution of the model.

In this paper we introduce a new approach for semiautomatic segmentation and analysis of the hippocampus volume. The segmentation is based on the geometric models of the Cerefy Brain Atlas [5] which were generated from the Talairach-Tournoux Atlas [6]. The essential steps of the approach are:

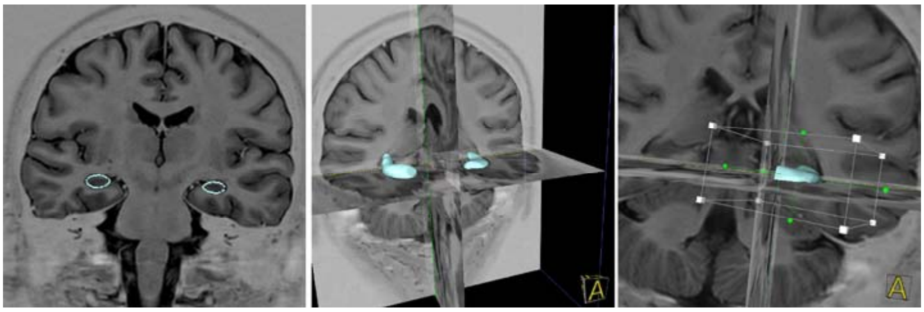
- Find the transformation of a geometric atlas model of the hippocampus to a T1-weighted MR volume using manual adjustment. This MR sequence provides a clear recognizability of the boundaries of the hippocampus.
- Compute the volume of the left and right hippocampus using the transformed atlas model
- Transfer the atlas model to T2-weighted volume using the computed trasnformation matrix
- Compare average intensities of the left and right hippocampus region in T2-weighted volume. Compared to T1-weighted images this sequence emphasizes the intensity of diseased tissues.

Compared to pure manual segmentation based on pixel painting the presented method provides a faster volumetry of the hippocampal structures for the diagnosis of temporal lope epilepsy. Therefore it turned out to be a promising method for clinical routine use.

## 2 Method

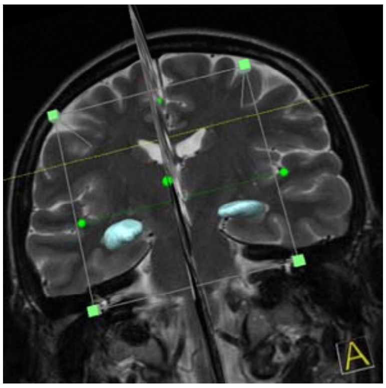
The presented segmentation approach consists of 5 steps which are subsequently explained.

**Fig. 2.** Manual adjustment of the hippocampus model by using the *Open Inventor* manipulator: Coronal slice contains the intersections of the atlas model with this slice(left). Using a 3D view of arbitrary slices to adjust the hippocampus in 3D (middle). The manipulator allows an easy handling of using geometrical transformation (right).



1. *Atlas coordinate system transformation:* The used atlas model is available in the Talairach space where the anterior commissure (AC) represents the origin of the related coordinate system.
   For a quick alignment the anterior (AC) and the posterior (PC) commissure must be identified within the volume data. Based on the approach in [7] the user has to set five separate landmarks using a triplanar view of the volume. The defined points span the Talairach space inside the volume dataset. Using the computed transformation matrix between these two coordinate systems the polygonal model of the atlas is then transformed into the volume coordinate system. Figure 1 shows the result after the alignment.
2. *Manual adjustment of the atlas:* In a second step the polygonal model must be adjusted, which is done by using a 3D viewer. For supporting the manipulation the object-oriented 3D toolkit *Open Inventor* is used. Using a standard manipulator of this library this kind of manipulation provides an easy way to transform the polygonal model correctly. For a comprehensive visual feedback the 3D viewer represents three arbitrary slices of the dataset. These slices are controlled by a triplanar view where each slice can be positioned arbitrarily in order to achieve an optimal orientation and selection. Furthermore the intersections of the atlas with the volume slices are displayed in the triplanar view. Figure 2 shows the results of this task.
3. *Volumetry of the registered model:* After manual registration the volume of the polygonal model is computed using the maximum unit normal component (MUNC) [8] algorithm.
4. *Atlas transformation to the T2-weighted dataset:* A corresponding T2-weighted MR volume is registered to the IR volume by using automatic voxel-based registration [9]. Using the registered volume the former manually defined atlas transformation is easily applied. Figure 3 shows the adjusted model in the T2 dataset.
5. *Comparison of intensity values:* For the final analysis of disease the average intensity value of each segmented hippocamus are compared.

**Fig. 3.** The above figure shows the adjusted atlas model to the registered T2-weighted volume.



## 3 Validation

At the Epilepsy Center of the University of Erlangen-Nuremberg a clinical study using 30 datasets, was carried out. The study was based on manual segmentation of the hippocampus in Inversion Recovery MR datasets. The segmentation was obtained by a medical expert on a slice by slice basis using pixel painting demanding more than 1 hour in average for a precise hippocampus segmentation.

The approach was applied in 4 clinical cases with the two volumes with matrix $380 \times 25 \times 512$ voxels with the respective size of $0.449 \times 3.6 \times 0.449$ $mm^3$.

After a short training required to get familiar with the 3D visualization tool the manual segmentation normally demands less than 5 minutes including landmarks setting, linear registration and computing the volume.

Table 1 shows the results of the compared methods. For patient 1 the computed volume of the two methods are very close. Small differences between the two methods but a clear differentiation between the volumes of the right and left hippocampus are noticeable for patient 3 and 4. In case of patient 2 the volume of the right hippocampus is different between the two methods.

Significant differences between the average values for the left and right hippocampus are an indication for temporal lope epilepsy.

## 4 Conclusion

A semiautomatic approach for linear registration and volumetry was presented. It provides a fast straightforward process for the purpose of registering MR data with a geometrical model of an anatomical atlas. The approach allows a linear registration using 3D visualization with interactive manipulation techniques for an intuitive registration and efficient segmentation of the hippocampus. The

**Table 1.** Computed volumes of the right (HR) and left (HL) hippocampus and the average value of the segmented voxels are shown. Significant differences between the two volumes and the intensities are an indication for temporal epilepsies.

| | Manual Approach Volume ($mm^3$) | | New Approach Volume ($mm^3$) | | Average | |
|---|---|---|---|---|---|---|
| Dataset | HR | HL | HR | HL | HR | HL |
| Patient 1 | 2909 | 1287 | 2848 | 1138 | 763 | 512 |
| Patient 2 | 1548 | 1922 | 2214 | 1929 | 864 | 441 |
| Patient 3 | 1661 | 2624 | 1695 | 2330 | 467 | 631 |
| Patient 4 | 2170 | 1508 | 2634 | 1542 | 580 | 470 |

outcome of the presented strategy showed good correspondence to pure manual segmentation and better delineation in complex and pathological situations.

As a major achievement, the previously required high time effort was significantly reduced and robust results were achieved. For the future, further automation is envisaged based on the experience of medical experts. A nonlinear deformation of the polygonal model will also contribute to achieve more accurate results of the volumetry.

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