# Automated approach for the segmentation of the incus and malleus middle ear bones in 3D CT images

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*Introduction*

The human auditory system includes the hearing and balance organs, and can be divided into three main elements: outer ear, middle ear and inner ear. The auditory ossicles are three very small bones: the malleus, incus and stapes, confined in the middle ear and coupled in chain. Their main function is to transmit sound energy from the tympanic membrane to the fluid-filled cochlea. As such, they are fundamental for hearing capabilities.

Accurate geometrical realistic models automatically build from common ear images is of huge demand for supporting 3D visualization and radiological diagnosis, for instance. Image segmentation, i.e. the partition of an original image in coherent structures, is a precondition of efficient and truthful analysis of the ear from images. For example, the suitable segmentation of the ear structures in each image slice of a 3D medical exam is critical for effective biomechanical simulation, surgical planning, and surgical implantology [1-2].

The purpose of the current paper is to present a fully automated computational solution to segment the incus and malleus ossicles in conventional 3D X-ray computed tomography (CT) images.

*Methods*

The segmentation solution developed was tested using a dataset comprising 21 CT volumetric images of the ear acquired using standard CT scans and protocols. The experimental cases were randomly selected from subjects that undergo a CT exam of the ear due to ear related pathologies. The dataset included images with partial occlusions of the ossicles, and their resolution varied from $0.162\times0.162\times0.6$ mm$^3$ to $0.166\times0.166\times1.0$ mm$^3$.

The automated segmentation solution developed is divided into two main steps. First, a coarse segmentation is attained based on the registration-based segmentation paradigm [3], i.e. the image under study is normalized by a template image previously built and then segmented. The goal of the second step is the fine tuning of the coarse segmentation, based on image threshold and morphological filters.

Dice's coefficient and the Hausdorff distance were used to compare the results of the automated segmentation with the ones of a semi-automated segmentation attained by an expert.

For visualization and inspection propose, the segmented images were used with the marching cubes algorithm to build 3D surfaces of the ossicles (Fig. 1).

*Results*

Regarding the Dice's coefficient, the mean agreement between the automated and semi-automated segmentation approaches was equal to 0.96, and the mean Hausdorff distance among the shapes obtained by these approaches was 1.14 mm.

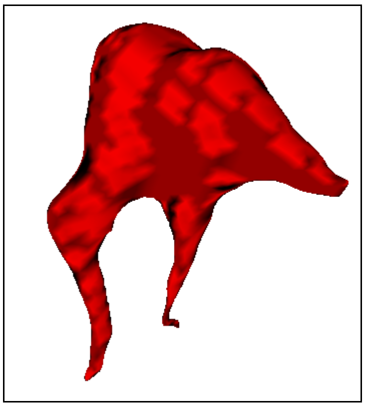

Figure 1: Example of a surface built based on the automated segmentation of the incus and malleus bones of a patient included in the experimental dataset.

*Conclusions*

A high agreement between the semi-automated and the automated segmentations was obtained (Dice's coefficient equal to 0.96). Having in mind that the slice spacing associated to the most part of the images was of 1.0 mm and, consequently, the distance between two neighbour voxels can be superior to 1.0 mm, it can be considered that mean value of the Hausdorff distance between the automated and semi-automated segmentations was very low.

In conclusion, it was verified that the fully automated segmentation of the incus and malleus ossicles in 3D images acquired using conventional CT scanners and standard protocols can be feasible and robust, even for patients with ear pathologies and when the ossicles are partially occluded. Thus, the solution developed can help efficiently radiologists and otolaryngologists in the evaluation of CT ear exams by providing accurate 3D model automatically built from the images under analysis.

*Keywords*: medical imaging, imaging analysis, ear segmentation, atlas-based segmentation, image registration.

*References*

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