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SHAPE MODELLING OF THE INNER EAR FROM MICRO-CT DATA

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Background: It is crucial to understand the anatomy and anatomical variability of the inner ear in order to improve the design and functionality of implantable hearing devices such as Cochlear Implants (CI). Statistical shape modelling of the inner ear provides a versatile tool that can aid numerous interesting Cochlear Implant applications, in particular implant design optimization and surgical planning.
The spiral-shaped cochlear of the inner ear presents an anatomy with small important features that can only be properly perceived in high resolution micro-CT scans of cadaveric specimens. The complex anatomy and the large data sizes make it a challenging dataset to handle and to build a shape model from.

Aims: To build a statistical shape model of the inner ear from high resolution micro-CT data.

Methods: 17 temporal bones excised from human cadavers were dried and scanned with a micro-CT system (Scanco Medical, Switzerland). The region of interest in the datasets was reconstructed in 24 micron isotropic voxels (resulting in approximately 6GB of data per scan).
Segmentation: The inner ear (cochlear and vestibular system) was segmented manually using ITK-SNAP[1]. The surfaces of the segmentations were extracted using Marching Cubes and post-processed using MRF surface reconstruction[2] to provide smooth and well-formed surface meshes.
Registration: One dataset was chosen as a reference. An initial rigid transformation aligning the center of mass and the principal directions was calculated. The principal directions are consistent due to the asymmetric shape of the inner ear. This was followed by a deformable registration using elastix[3]. A multi-level B-spline grid minimizing sum of squared differences with bending energy regularization was used. The registration was between the segmentation images to reduce the influence of the noise in the micro-CT data.
Model Building: The transformations were applied to the reference surface model, to create surfaces representing the anatomy in the individual datasets with point correspondences. Using Statismo[4] a point distribution model (PDM) was built (Figure 1-3).
Evaluation: The quality of the model is constrained by the accuracy of the registration which is evaluated against the ground truth segmentation using Dice score and Hausdorff distance (the latter calculated with the 'ground truth' surface model).

Results: A PDM of the inner ear containing 466k vertices and 16 modes of variation (Figure 1-3). The average Dice score was 0.96 ± 0.01 and average Hausdorff distance 0.69 ± 0.24 mm.

Conclusions: An inner ear shape model has been built using open source libraries and tools. The model has more anatomical detail and modes of variation than what has previously been reported.

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(a) (b) (c)

Figures: (a) Mean shape. (b) Close up on the cochlear. (c) 1st mode showing the change in overall size.