OTOVIRT: An image-guided workflow for individualized surgical planning and multiphysics simulation in cochlear implant patients

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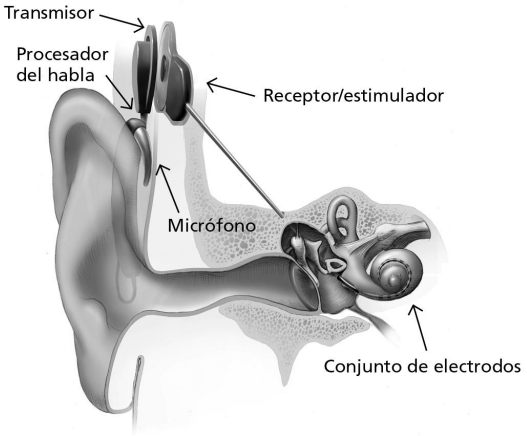
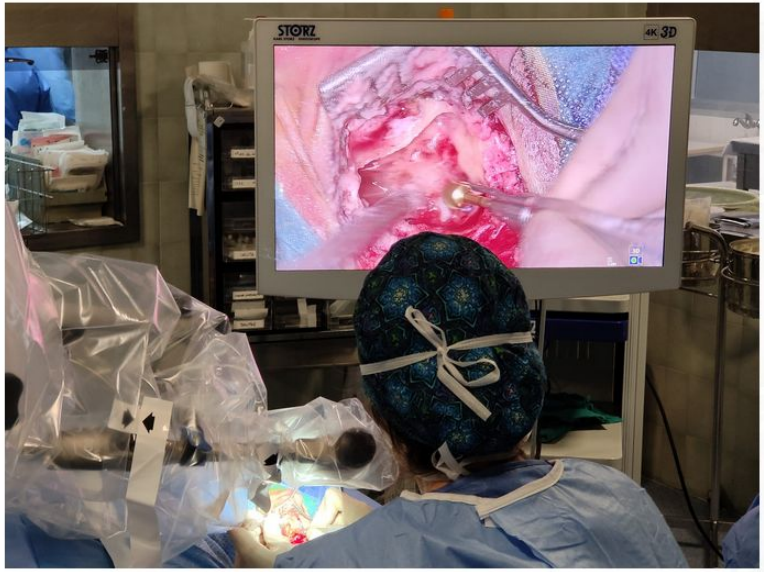
Introduction

1. The problem: surgical inner-ear interventions present a big challenge as there is a high anatomical complexity
   a. Training time
   b. Resources
   c. Technological complexity: Cochlear Implants (CI)





Deep NL,Dowling EM,Jethanamest D. "Cochlear Implantation: An Overview." *Journal of Neurological Surgery. Part B, Skull Base*, *U.S. National Library of Medicine*. 2019;80(2):169-177. doi:10.1055/s-0038-1669411

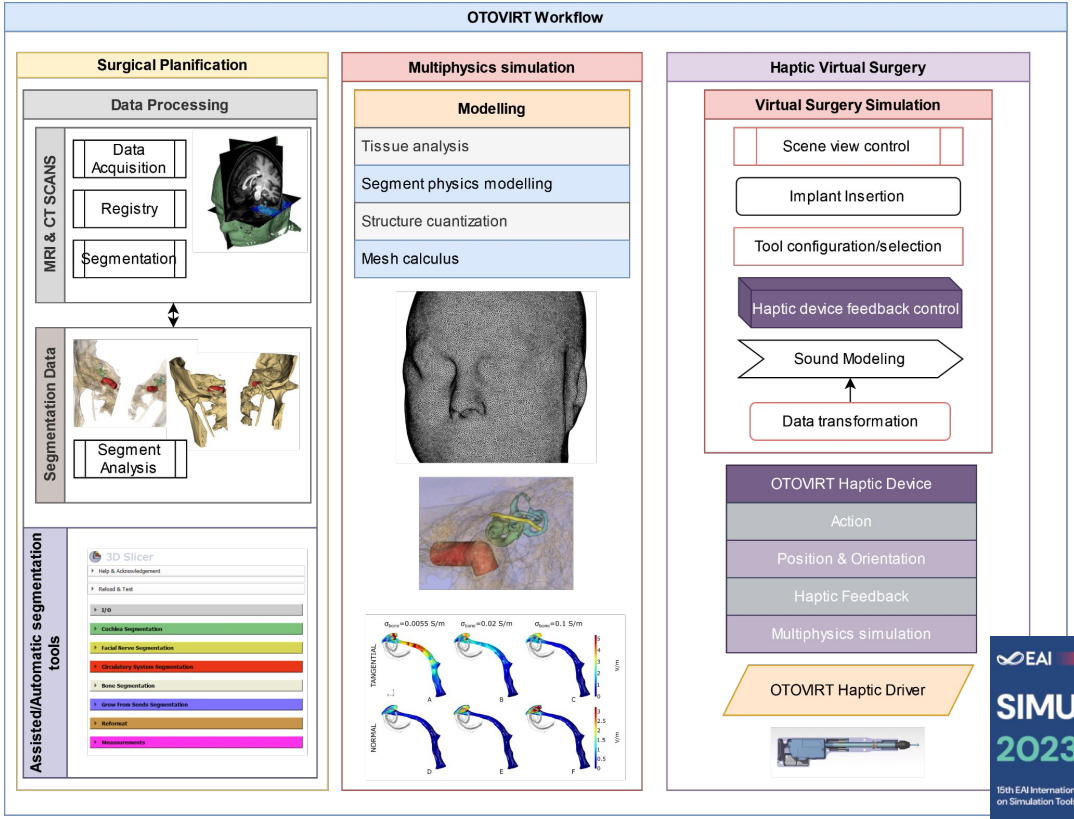
Wiet, Gregory J et al. "Otologic Skills Training." *Otolaryngologic clinics of North America.* 2017; vol. 50,5: 933-945. doi:https://doi.org/10.1016/j.otc.2017.05.005

Objectives

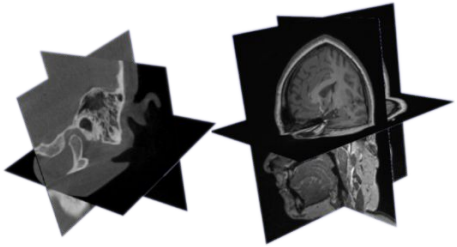
1. Main goal: to introduce a workflow for the surgical simulation of inner-ear interventions in order to solve the mentioned needs
2. Secondary objectives:
   a. Design and conceptualization: design requirements, modularity, applications, etc.
   b. Anatomical model acquisition from real patients
   c. Results validation

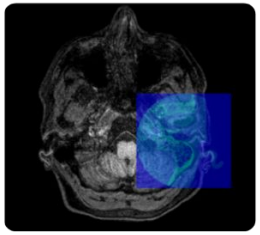
Materials and methods

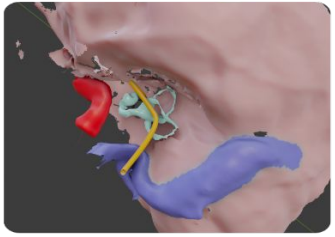
1. Input images
2. Open source software: 3D-Slicer, Blender, etc..
3. Tool and devices integration
4. Semi-Automatic processes
5. Precision and validation of the models

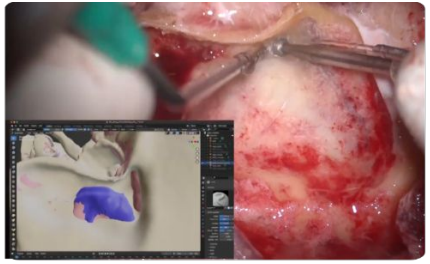


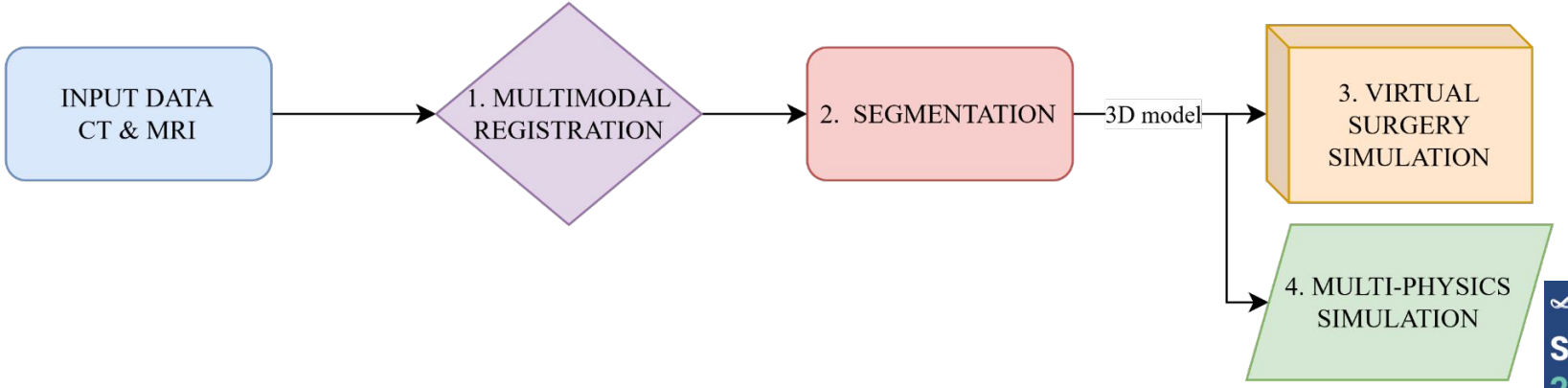
Results: Pipeline OTOVIRT





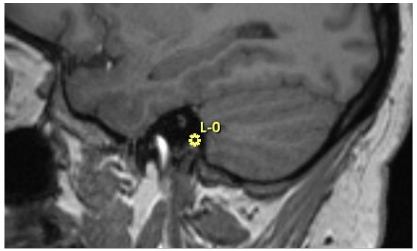


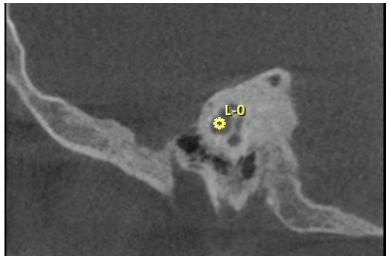


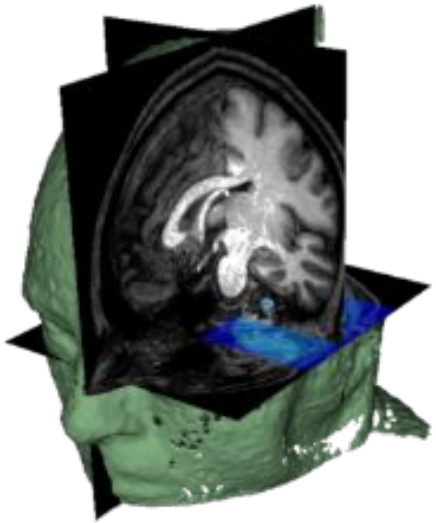


Results: *Multimodal registration*

- Available images: CT and MRI
- A first step that is key: models presented in the same anatomic space of coordinates
  - Manual registration based in the localization of key reference points
  - Important anatomic points: present in CT and MRI



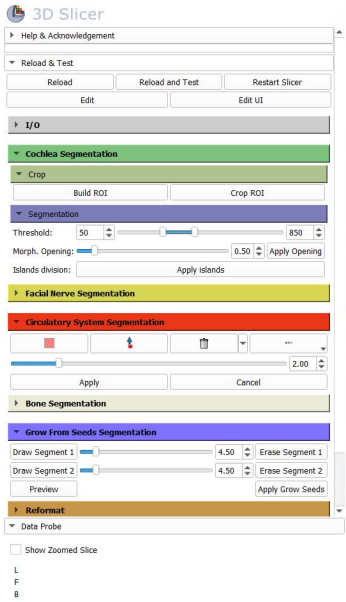


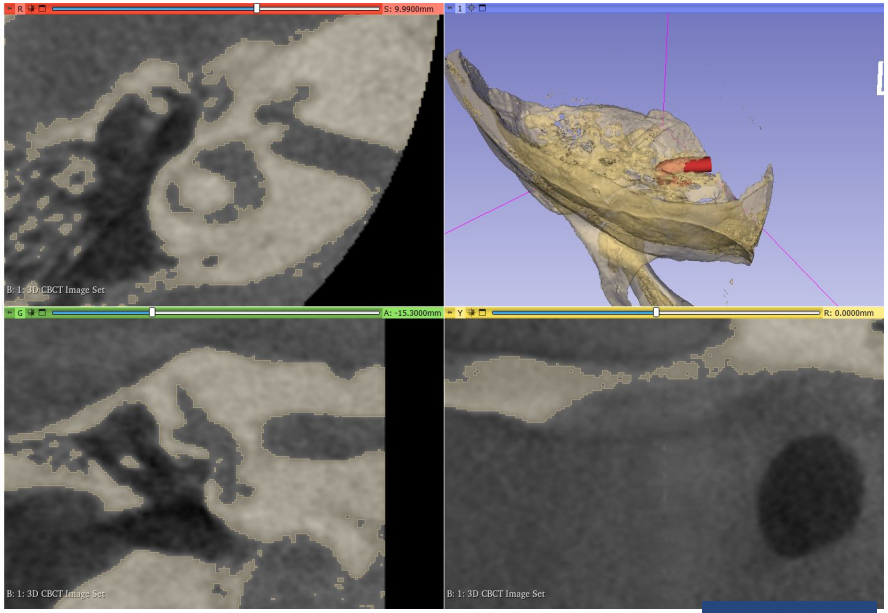


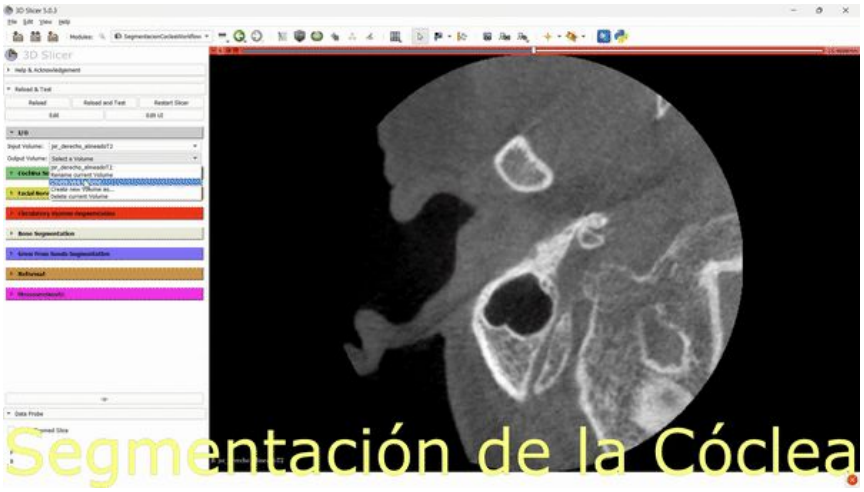
Results: *3D Slicer segmentation extension*

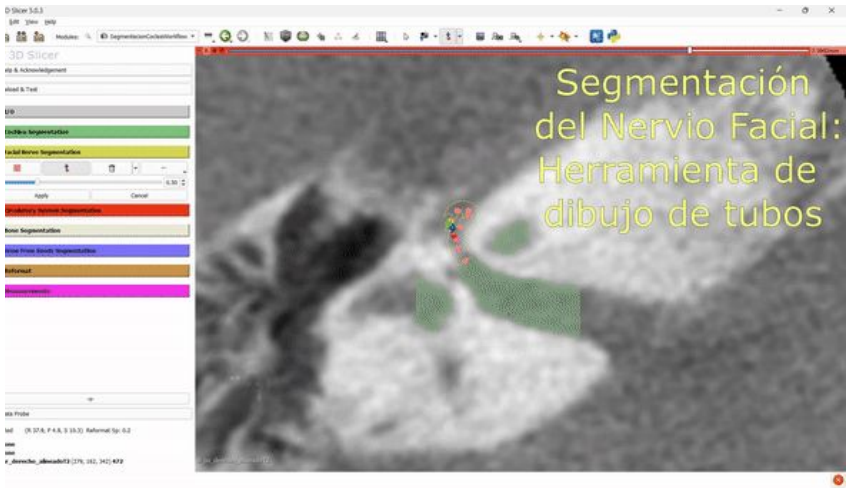
A 3D Slicer extension is developed for the segmentation of relevant structures. Includes the following sections:

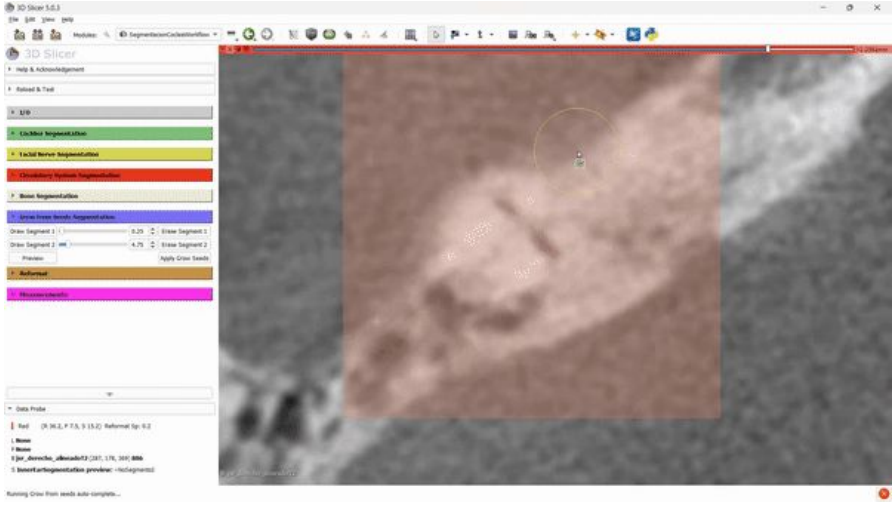
- Cochlea segmentation
- Facial nerve segmentation
- Internal carotid segmentation
- Temporal bone segmentation
- Region Growing segmentation
- Transformations
- Measurements and guided sections






Segmentación de la Cóclea


Segmentación
del Nervio Facial:
Herramienta de
dibujo de tubos



Extensión de 3D Slicer para la segmentación de las estructuras del oído interno

ORL-HUVM

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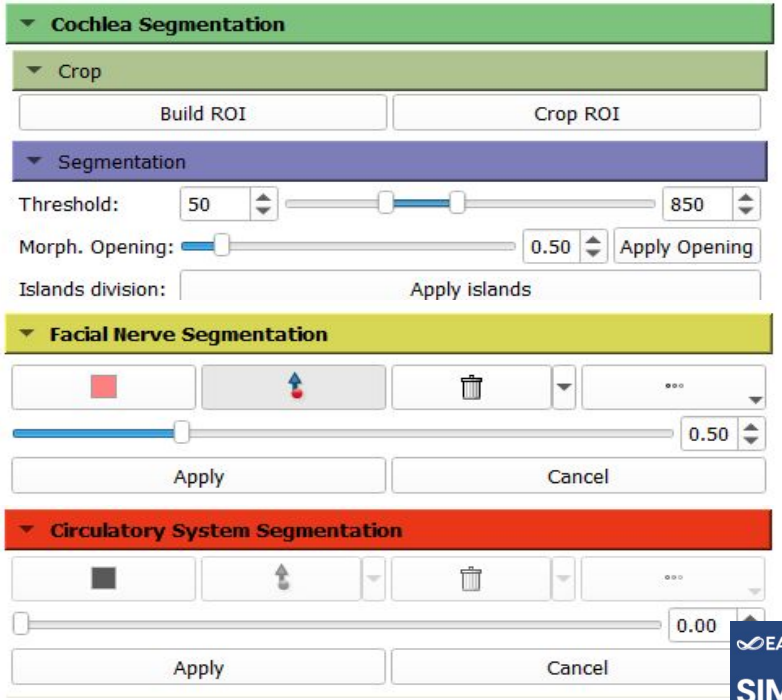
Results: *3D Slicer segmentation extension*

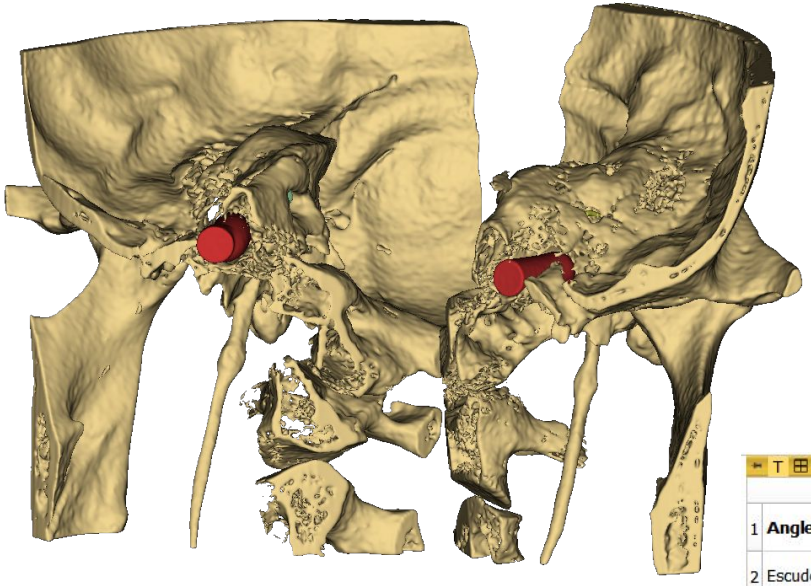
Features of some of the sections:

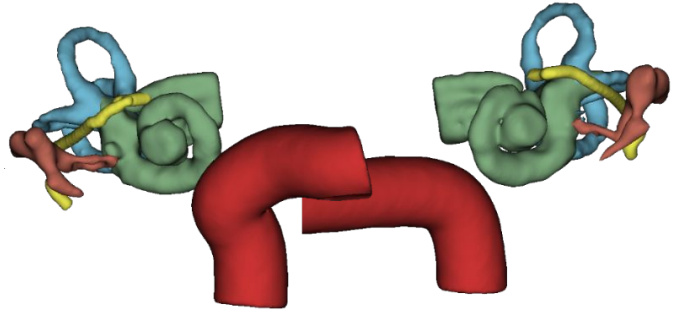
- Cochlea Segmentation:
  - Crop subsection:
    - Buttons to generate a ROI and captura the intersection with the CT Scan
  - Segmentation subsection:
    - Thresholding
    - Morphological opening (erode+dilate)
    - Connectivity filtering
- Facial Nerve and carotid sections:
  - Buttons to place fiducials
  - Interpolation between fiduciary points to generate a tubular structure



Results: *3D models generated from six patients*

OTOVIRT workflow is tested in a clinical environment with images from real patients. It is possible to obtain realistic anatomical models and multiple data and measures.

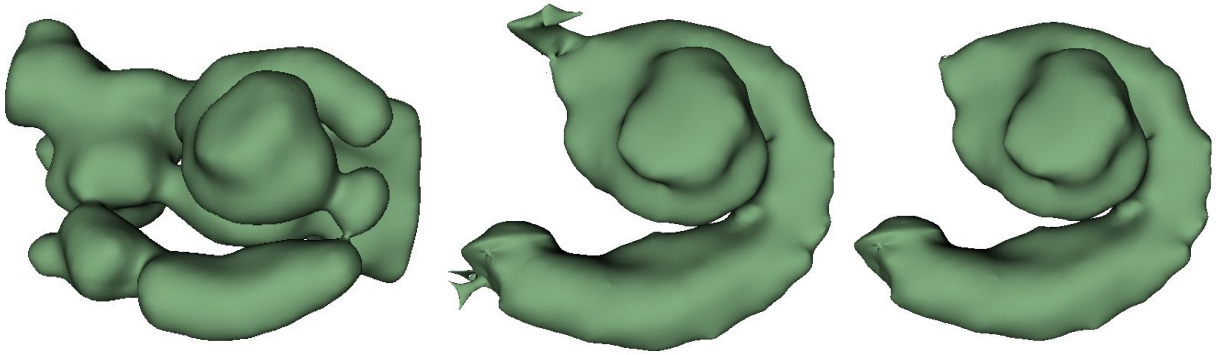




	A	B	C	D	E	F
1	**Angle of insertion**	**0**	**14**	**28**	**42**	**56**
2	Escude estimated Length	0.0	1.2650372120246722	2.4608571963071824	3.5946431381621626	4.672514987741

Results: *Validation of anatomical models*

- Obtained models are validated by experts
- An open repository is used to assess the functioning of the tools



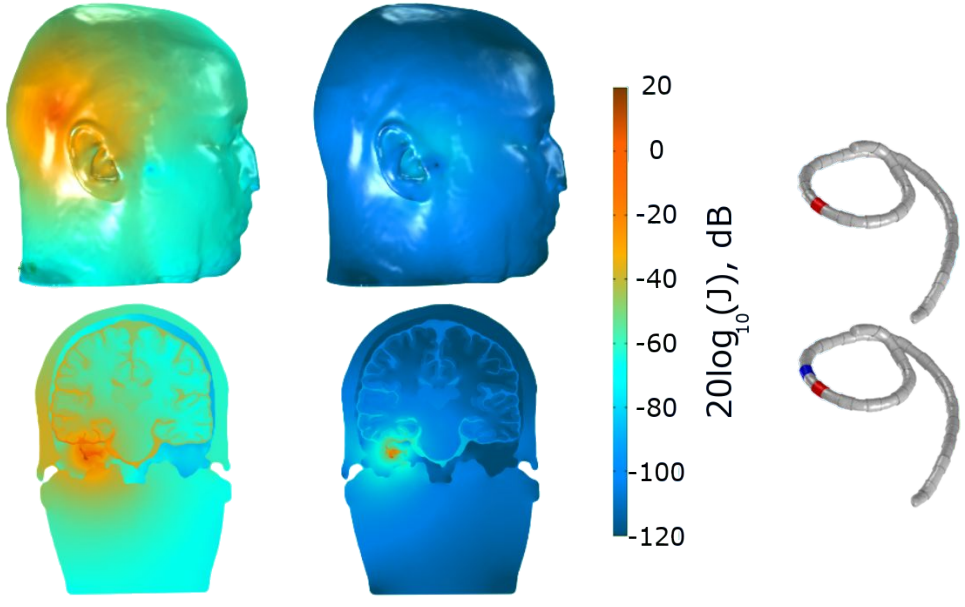
	Cochleo-Vestibular System	Facial Nerve	Cadena osicular
Subject 1	0,88	0,71	0,82
Subject 2	0,81	0,77	0,82

Sieber, D *et al.* "Data descriptor: The openEar library of 3D models of the human temporal bone based on computed tomography and micro-slicing". *Scientific Data*. 2019;*6*. https://doi.org/10.1038/sdata.2018.297

Bag S., Kumar SK., Tiwari MK., "An efficient recommendation generation using relevant Jaccard similarity". *Information Sciences*. 2019; vol 483 pp-53-46. doi: https://doi.org/10.1016/j.ins.2019.01.023

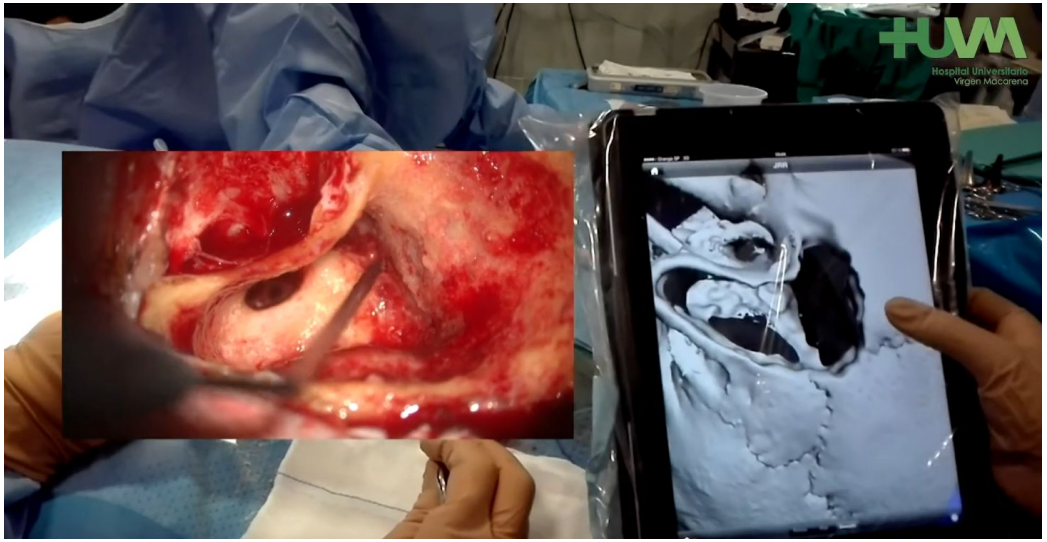
Results: *Multiphysics simulation*

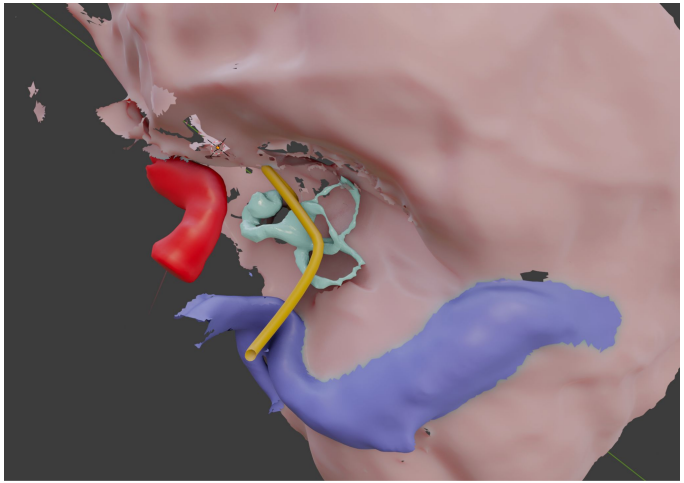
- With the obtained models it is possible to analyze the best stimulation procedure

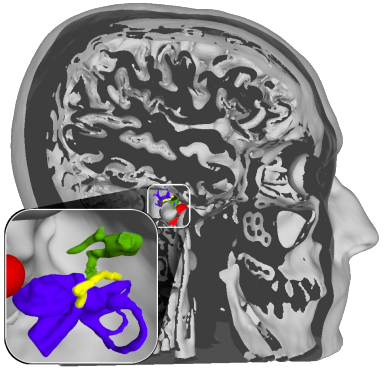


Results: *Virtual surgical simulation*

- The virtual surgical simulation is performed successfully with the use of the previously obtained models







EAI SIMUtools
SIMUtools 2023
15th EAI International Conference on Simulation Tools and Techniques
December 14–15, 2023
Seville, Spain


We can observe the digastic ridge and facial nerve

Conclusion

-The pipeline provides a base workflow that will be developed in a systematic methodology for the surgical planning

-The work is based in open-source software. This eases the access for the community and allows for future improvements

-Support systems can reduce patient's risk and ease the planification, improve understanding and surgical efficiency

-Simulation of procedures proves efficient and capable. The use of these tools during training also has huge potential

Demo ext. Slicer

Demo simulation

Clinical case of use: example

Future lines of action

1. Improve pre-processing
2. Release of an image repository with 3D models for the community
3. Improvements in the 3D Slicer extension for its future publication
4. Development of a 3D Slicer extension for the segmentation of the cochlear implant
5. Use of AI for the image processing: segmentation and registration could be automatized

Demo ext. Slicer

Demo simulation

Clinical case of use: example

Thank you very much!

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Other resources:

- Programa de implantes cocleares: generalidades y red de implantes cocleares
- Implantes cocleares: vía clínica.
- Flujo de pacientes

Demo ext. Slicer

Demo simulation

Clinical case of use: example