CREATING THE SYDNEY YORK MORPHOLOGICAL AND ACOUSTIC RECORDINGS OF EARS DATABASE

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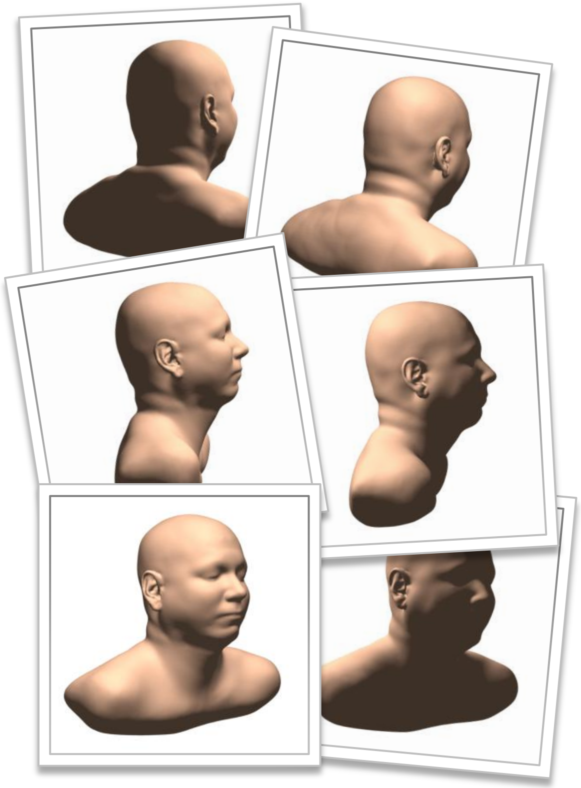
OUTLINE

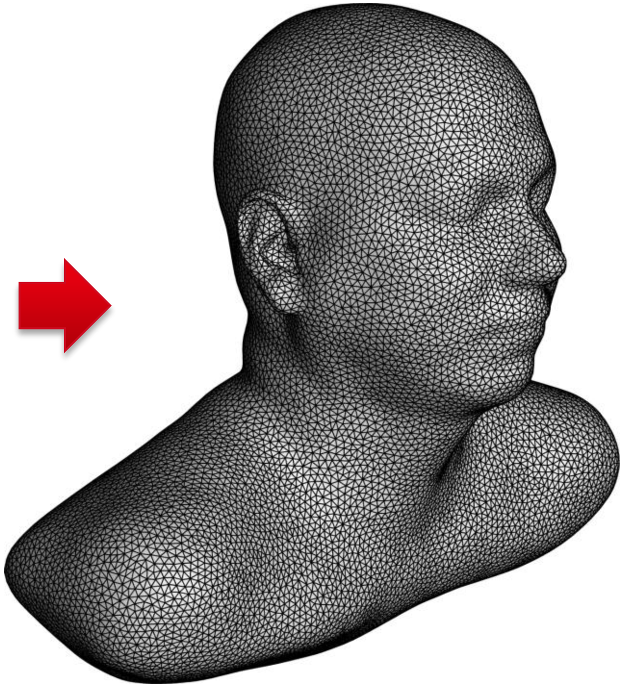
- Introduce a “Holy Grail” in 3D Audio
- Describe the SYMARE database
- Genesis of the database
- Preliminary validation of the data.

INTRODUCTION

› The Problem: Customize 3D audio for listeners based on 2D photos



2D Photos



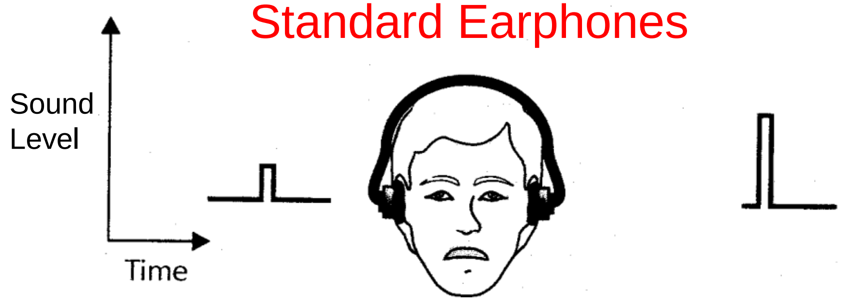
Parameterized
3D Head model

Personalised filters
for 3D audio

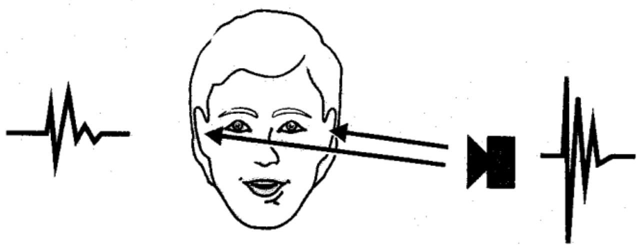
HEAD-RELATED IMPULSE RESPONSES

› Head-Related Impulse Responses (HRIRs): are acoustic filters for earphones that produce 3D Audio

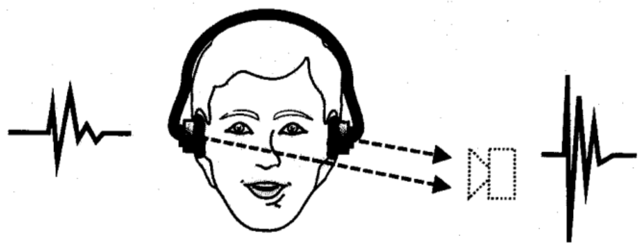
Standard Earphones



Normal Spatial Hearing



Earphones 3D Audio using HRIRs

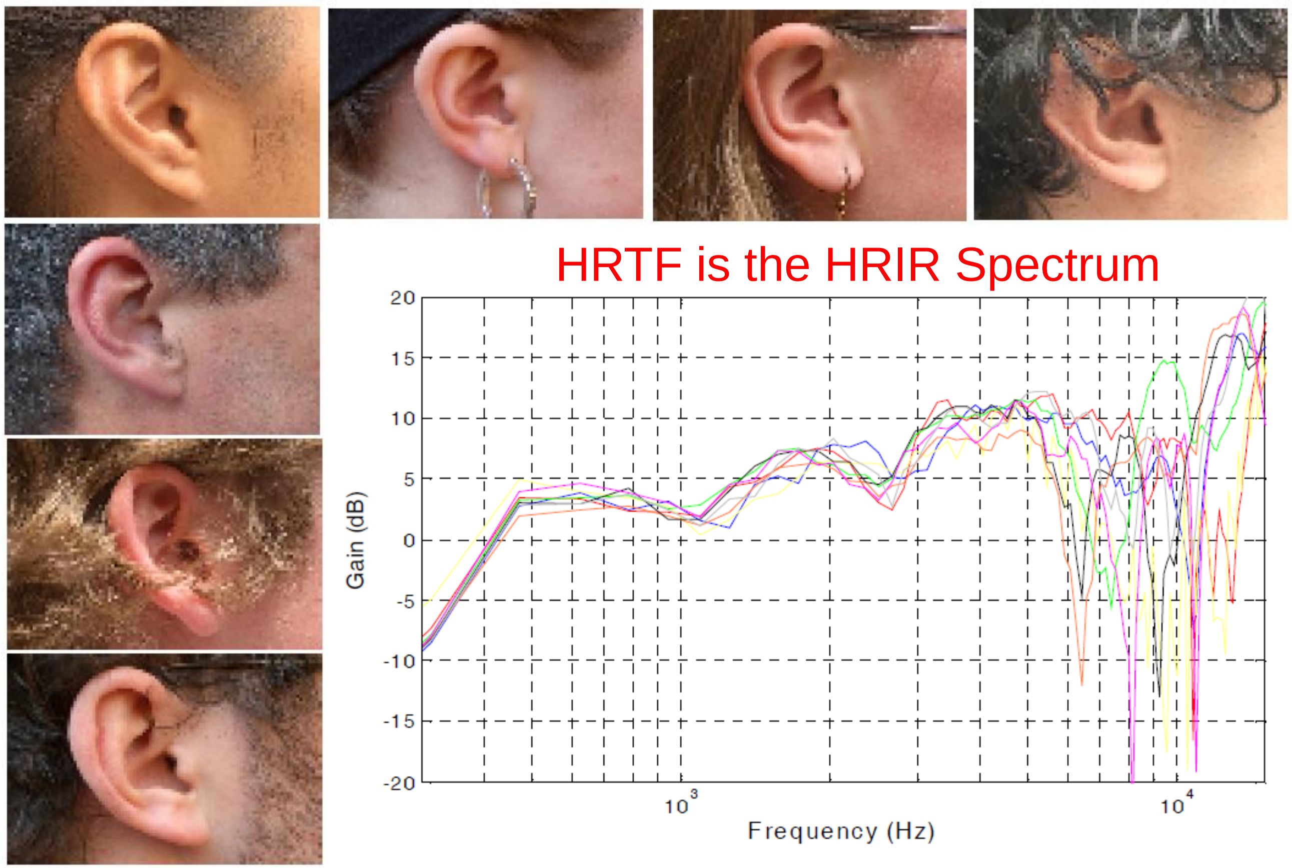


HEAD-RELATED IMPULSE RESPONSES

› Acoustically measuring HRIRs can be difficult and time-consuming. It would be better if we could predict HRIRs from morphology.

HEAD-RELATED IMPULSE RESPONSES

- Listener's ears differ and so do their HRIRs



THE SYMARE DATABASE

Sydney York Morphological and Recording of Ears Database

› The SYMARE database is a joint effort between the universities of Sydney and York.

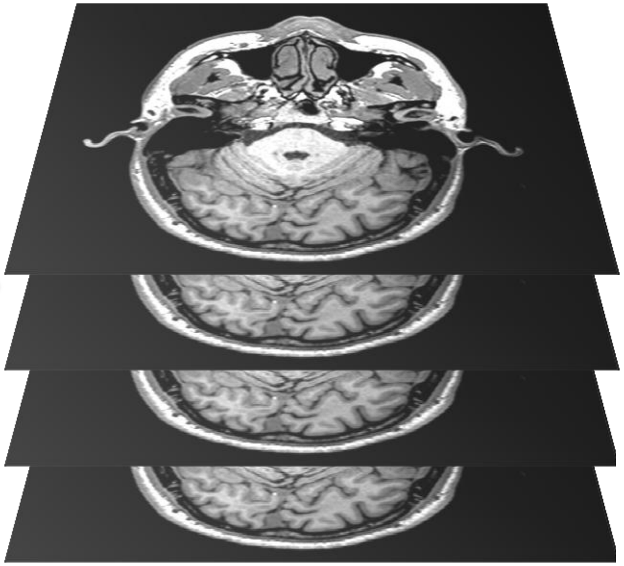
› The database contains morphological and acoustic data for 60 subjects. For each subject, the database provides:

- The subject's measured HRIRs for approximately 400 directions.
- High-resolution surface meshes of the head and combined head and torso at varying resolution *suitable for acoustic simulation*. In the meshes with the highest resolution, the size of the elements is on the order of 1 mm.
- Two sets of HRIRs simulated by applying the Fast-Multipole Boundary Element Method (FM-BEM) to the head-only and head-and-torso meshes.

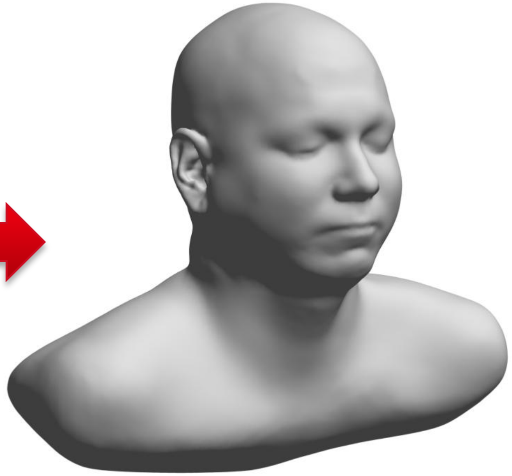
ACQUISITION OF HEAD AND TORSO MESHES

Acquiring Morphological Data

MRI scanning



DICOM images

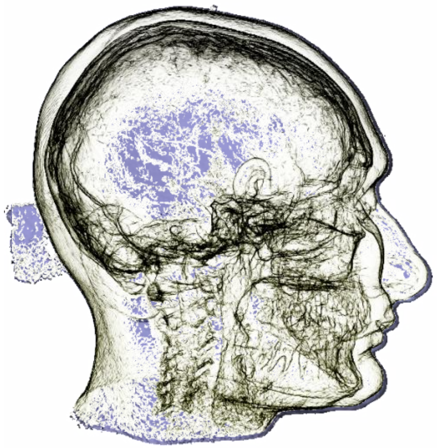


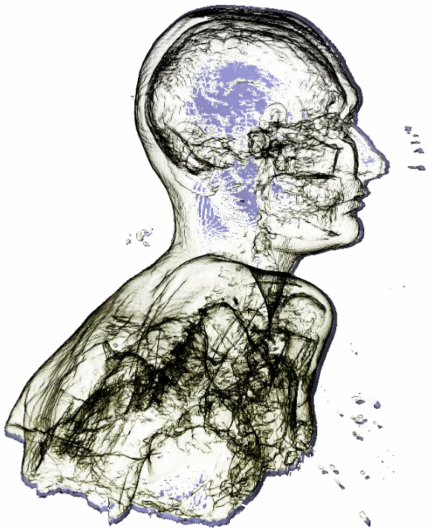
Surface mesh

FROM MRI SCANS TO 3D SURFACE MESHES

Generation of Surface Meshes

- For each subject, 2 MRI scans were performed: a high resolution scan of the head and a lower resolution scan of the head and torso.
- The surface meshes were first obtained by extracting iso-surfaces from both sets of MRI images.



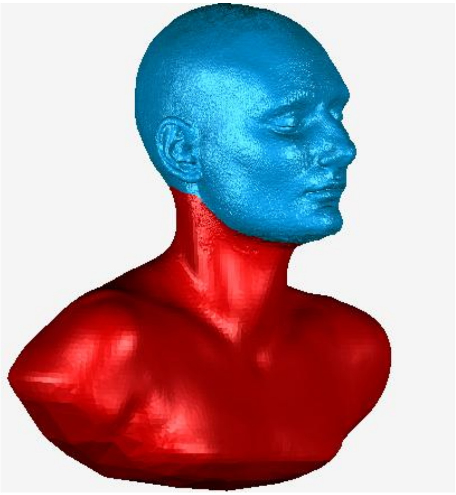


Some artifacts are present inside and outside the mesh. These artifacts were removed manually.

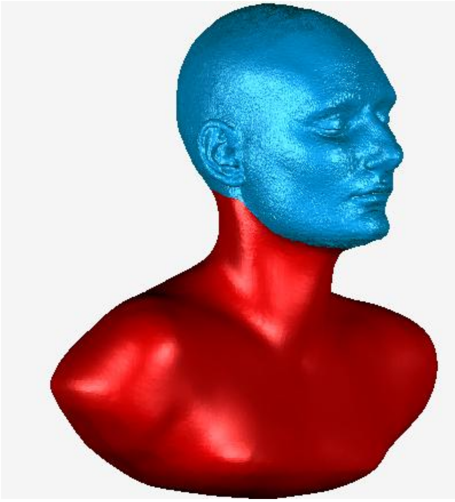
PREPARING SURFACE MESHES

Generation of Surface Meshes

- The high resolution head-only meshes were aligned and merged with the low-resolution torso mesh.
- The torsos' surfaces were smoothed.



Before smoothing the torso

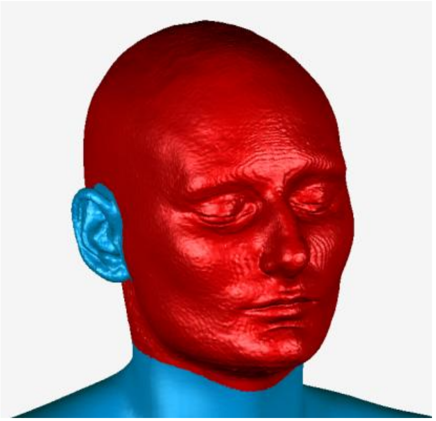


After smoothing the torso

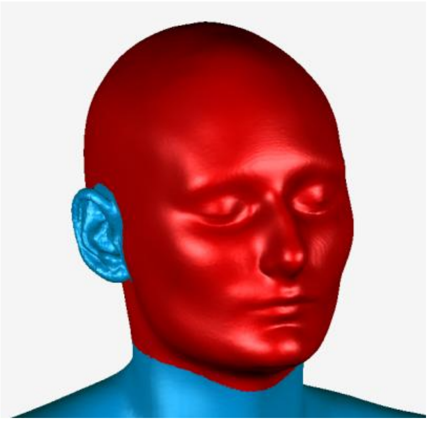
PREPARING SURFACE MESHES

Generation of Surface Meshes

- The meshes were re-meshed so that the triangular faces are as equilateral as possible.
- The heads (except the ear pinnae) were then smoothed.



Before smoothing the head



After smoothing the head

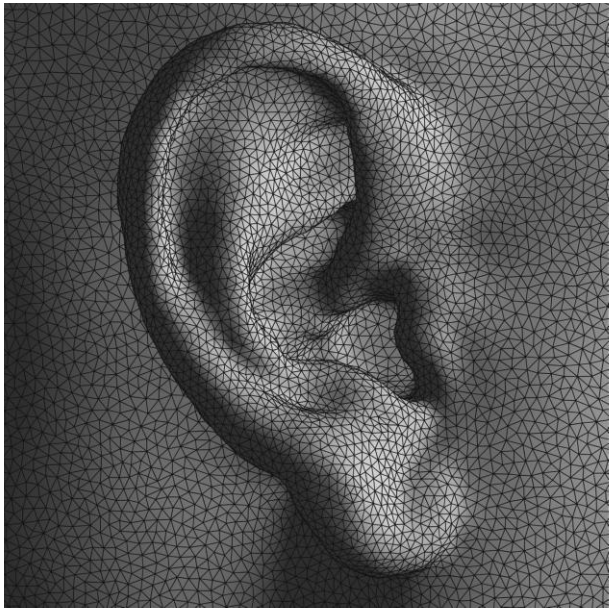
Triangle surface elements satisfy:

1. maximal to minimal edge length ratio < 5
2. Smallest angle > 15º
3. Largest angle < 160º

FINAL MESHES

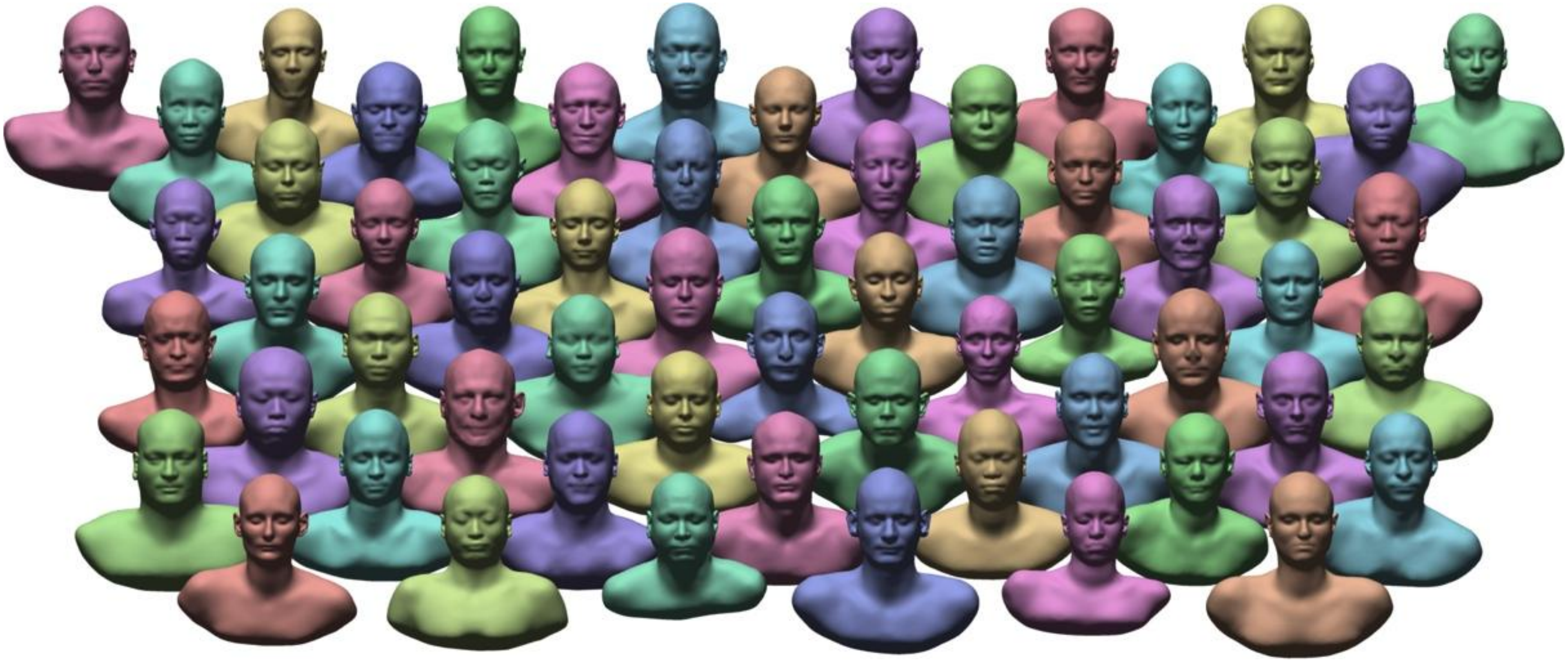
- The heads were separated from the torso to create head-only meshes.
- The Head-only and Head-and-Torso meshes were then re-meshed at various resolutions.

High-resolution Head-and-Torso mesh (~150k elts., f_{max}=16kHz)



Detail of a High-resolution Head-only mesh (~130k elts., f_{max}=20kHz)

FINAL MESHES



Terracotta Army in Xi’an China

FINAL MESHES

FM-BEM SIMULATIONS

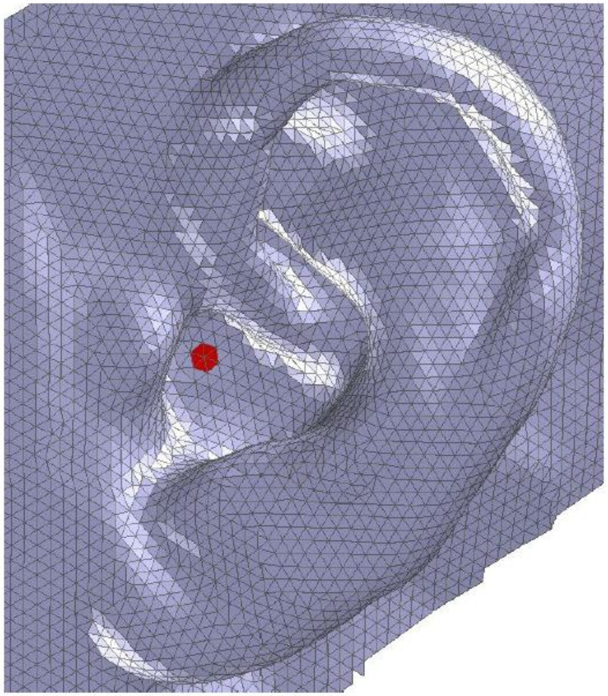
- The subjects HRTFs were simulated using Coustyx, a Fast-Multipole Boundary Element Method (FM-BEM) software.
- The size of the mesh elements determine the maximum frequency at which the BEM simulation can be done:

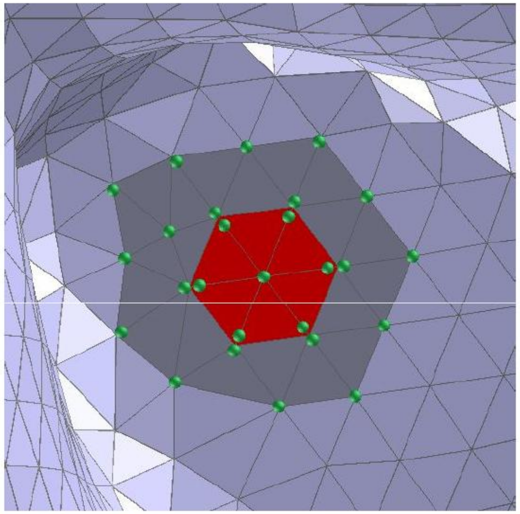
$$f_{\max} = \frac{c}{6\ l_{\max}}$$

where
- c is the speed of sound (~ 340 ms^{-1})
- l_{max} is the maximum edge length

- For each subject, two BEM simulations were performed:
  - Using a low-resolution Head-and-Torso mesh, up to 5.6 kHz.
  - Using a high-resolution Head-only mesh, up to 17 kHz.

Helmholtz Integral Equation Collocation Method with Chief Points



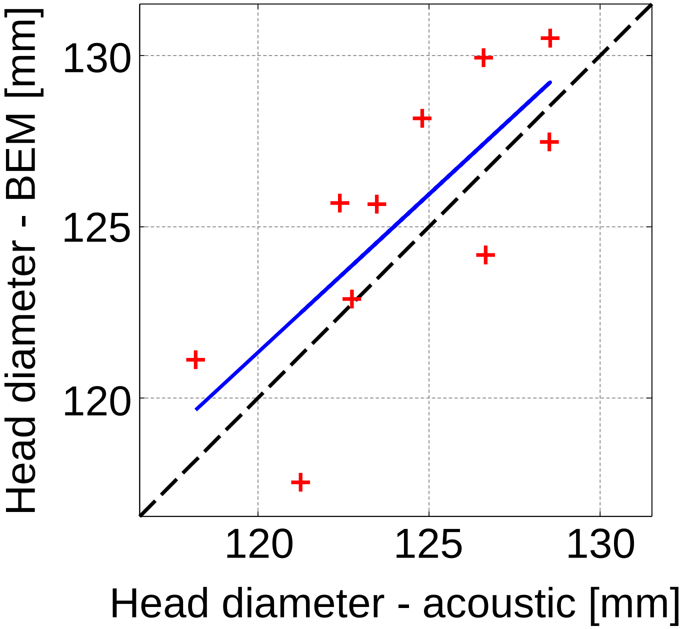


Use Reciprocity: $P(E,S_i) = P(S_i,E)$ to derive all HRTFs in one go.

Source placed in the ear; apply equivalent velocity boundary condition

ITD COMPARISON

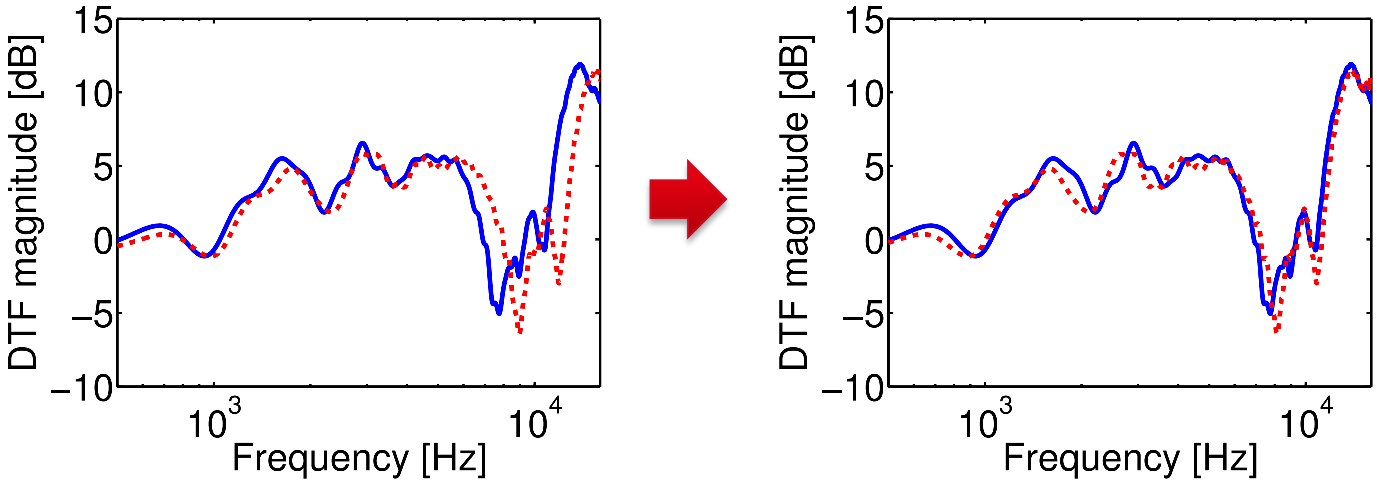
› We calculated the Interaural Time Delays (ITDs) for both the measured and simulated sets of data (Head-and-Torso meshes). We then applied Kuhn’s model to estimate the corresponding effective head diameters.



The difference in the effective diameters in on the order of a few percent.

FREQUENCY SCALING

› We applied Middlebrooks' frequency scaling technique to estimate the scaling factor that minimises the mismatches between the measured and simulated HRTF data.



Subject	1	2	3	4	5	6	7	8	9	10
Head only	1.053	1.031	1.099	1.042	1.064	1.020	1.020	1.075	1.020	0.990
Head & T.	1.021	1.010	1.031	1.010	1.010	1.010	1.020	1.031	1.020	1.053

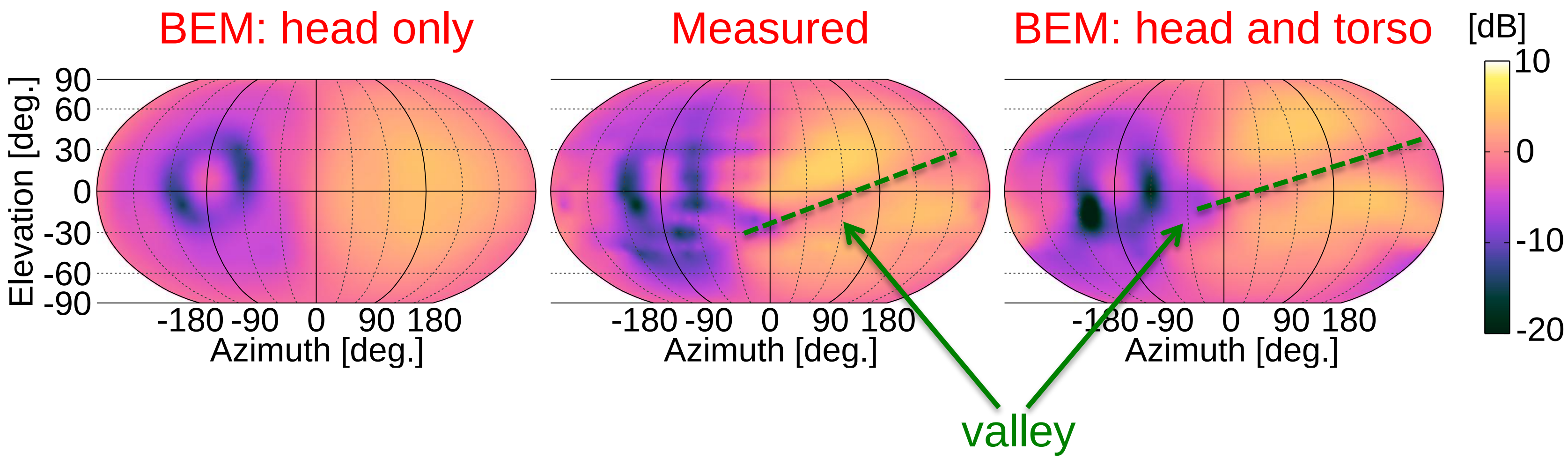
Frequency scaling factors for Subjects 1 to 10

SPATIAL FREQUENCY RESPONSE SURFACES

- A Spatial Frequency Response Surface (SFRS) is defined as the magnitude of the HRTFs for every direction at a given frequency. It characterises the directivity of the ear at this frequency.

INFLUENCE OF THE TORSO

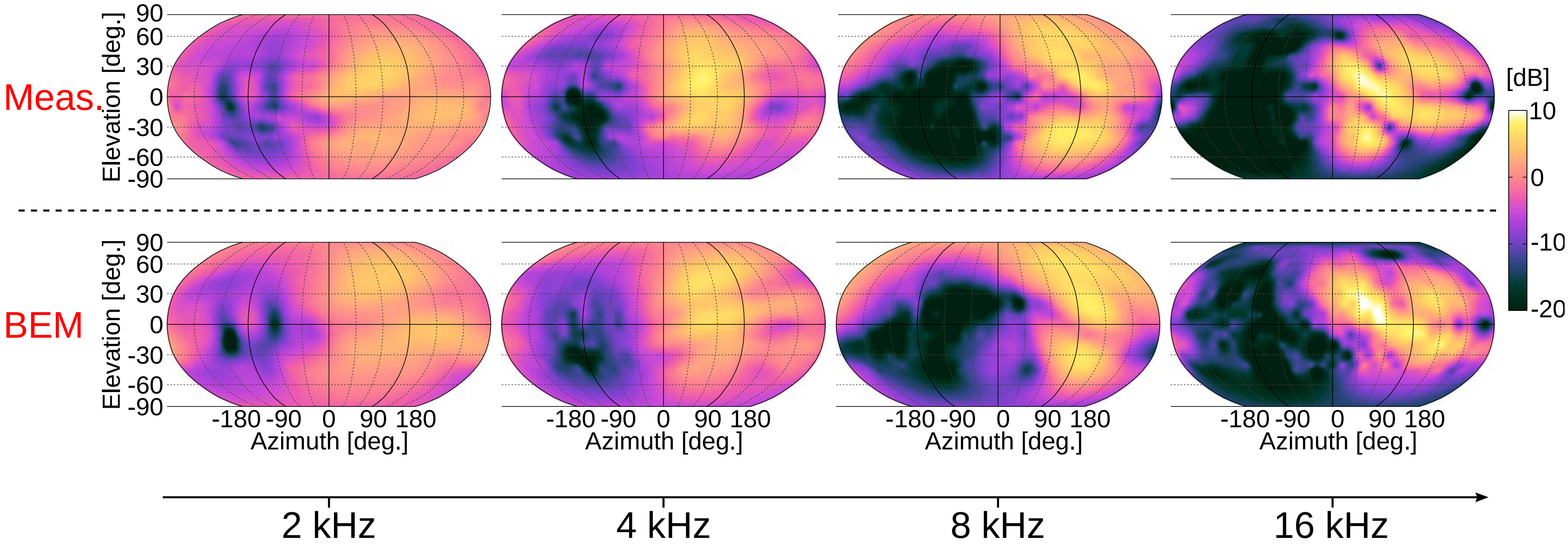
› We compared of the data obtained via BEM simulation using the Head-only meshes with that obtained using the Head-and-Torso meshes. The figure below compares Subject 1’s SFRS’s at 2kHz.



Important HRIR features are present only in the data corresponding to the head-and-torso mesh.

COMPARING SFRS'S: VISUAL INSPECTION

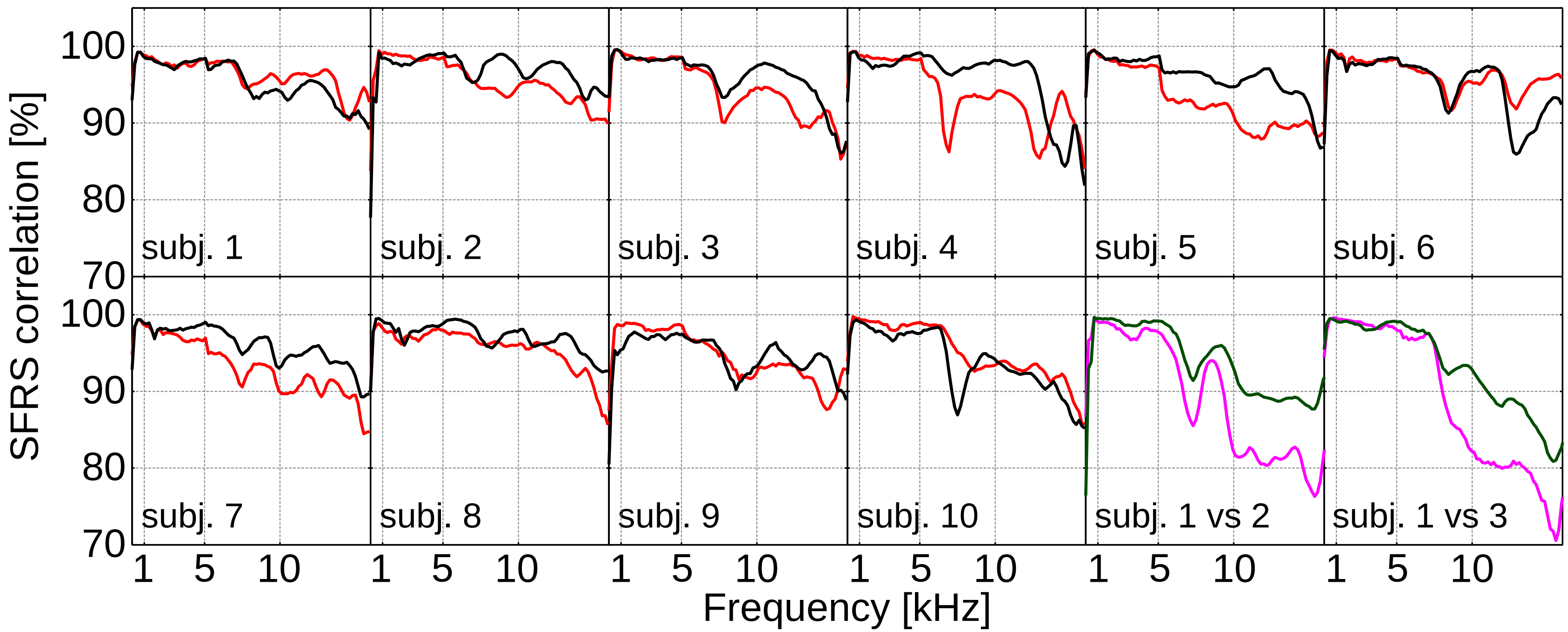
› Comparison of SFRS's corresponding to the measured and simulated data sets (the Head-and-Torso data is used below 5 kHz):



Many of the features of the SFRS corresponding to the measured data set are present in the BEM-simulated data set.

COMPARING SFRS'S: SPATIAL CORRELATION

- Spatial correlation between the SFRS's corresponding to the measured data and that corresponding to the simulated data, as a function of the frequency:



The simulated HRIR data captures some of the individual characteristics of the outer ear acoustics.

THE END

Thanks for your attention.

http://www.ee.usyd.edu.au/carlab/index.htm