Supported by the IEEE Signal Processing Society Challenge Program

Listener Acoustic Personalisation Challenge 2024

Rules and Numbers

Award Ceremony @ EUSIPCO 2024

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101017743

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Grant agreement ID: 101017743

DOI

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EC signature date

1 December 2020

Start date	**End date**
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Total cost

€ 5 651 042,50

EU contribution

€ 5 651 042,50

Coordinated by

IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE

United Kingdom

Transforming auditory-based social interaction and communication in AR/VR

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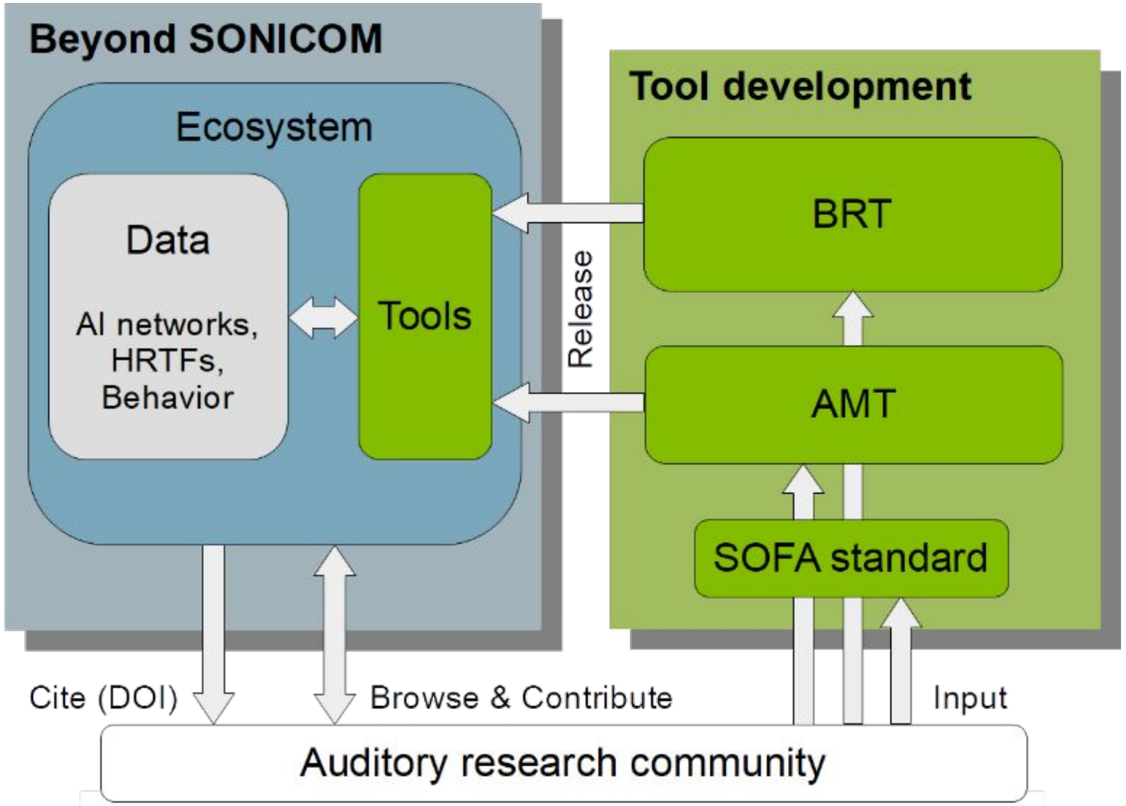
Why are we doing SONICOM?

- To tackle some of the **open challenges** in the **immersive audio domain**
- To investigate the impact of immersive audio beyond sensory perception
- To explore new future applications and products related with these technologies

To do this through a collaboration between different institutions who have already done extensive research in this area in the past, and who are now willing to work **TOGETHER** on these topics and build bridges among different communities.



Intro

The LAP Challenge aims at providing a platform where researchers can explore challenges (**2 - for the time being**), advance the state of the art, and contribute to the development of standardized metrics for personalised spatial audio.

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Motivations

The LAP Challenge would be:

- a comprehensive and objective benchmarking campaign
- a sustainable basis for further research beyond SONICOM
- reproducible research

The LAP Challenge would investigate

- acoustic and non-acoustic factors in the technological mediation
- multisensory integration of audio in space (…is a path to…)

LAP 1st edition 2024 - Focus on HRTF data *quality*

1. Data normalization
2. Spatial density
3. Influence of the measurement setup (i.e., different equipment, different room, different positions and distances, etc.)

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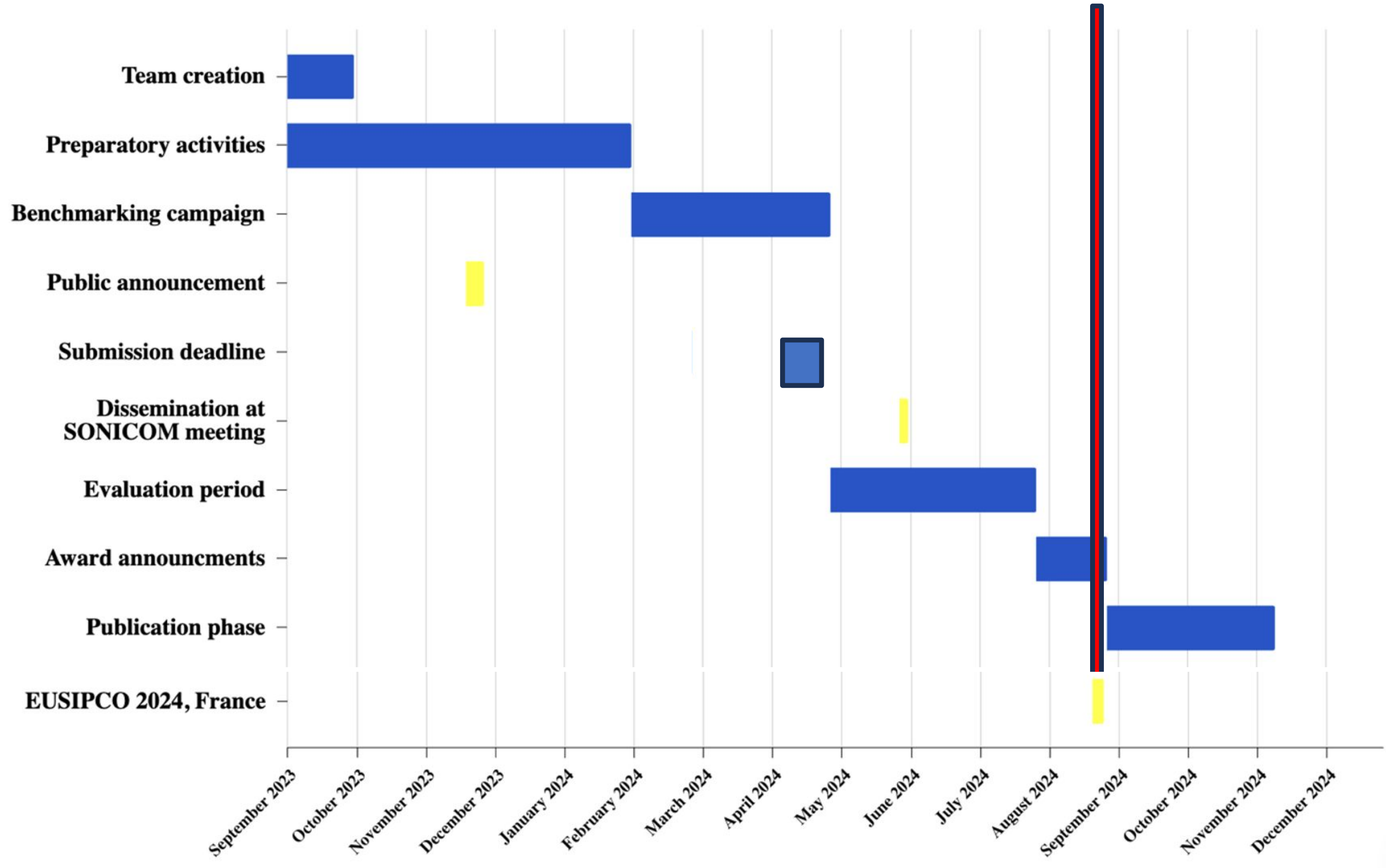
The roadmap of LAP 2024



- ~~Task specifics released: **March 27, 2024**~~
- ~~Evaluation code released: **April 4, 2024**~~
- ~~Submission deadline: **June 25, 2024**~~
- ~~Evaluation and invitations to the winners: **July 15, 2024**~~

- Award ceremony: **August 29, 2024 (EUSIPCO 2024 – Lyon)**

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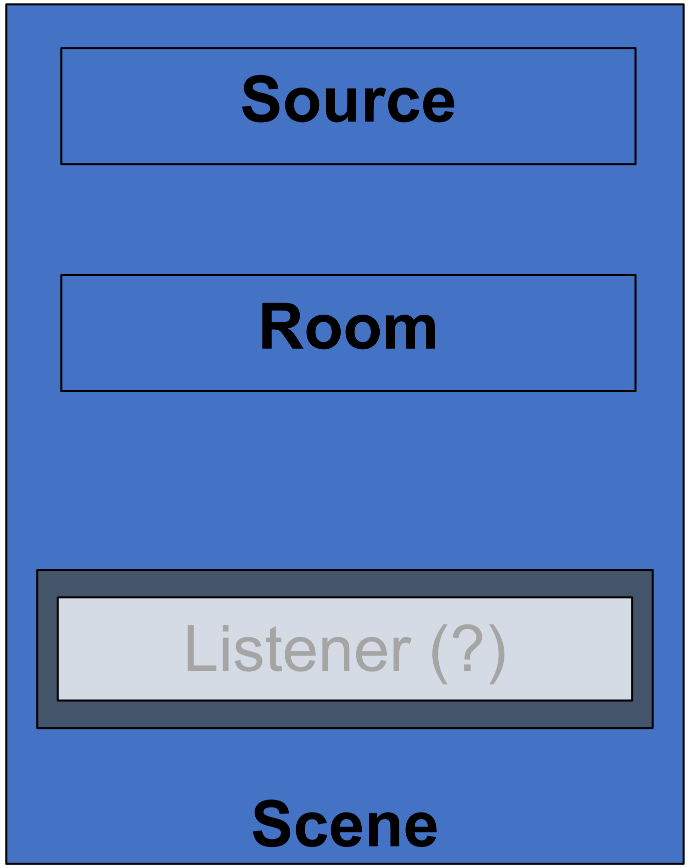
Other Challenges
in the Acoustic Domain

- Acoustic Source Localization and Tracking (LOCATA) challenge (Evers et al.,2018)
- Acoustic characterization of environments (ACE) challenge (Eaton et al., 2016)
- Detection and classification of acoustic scenes and events (DCASE) challenge (Stowell et al. 2015)
- Improving music listening for those with hearing impairment (CADENZA)
- Many others …

No challenges focus on the human receiver!!!



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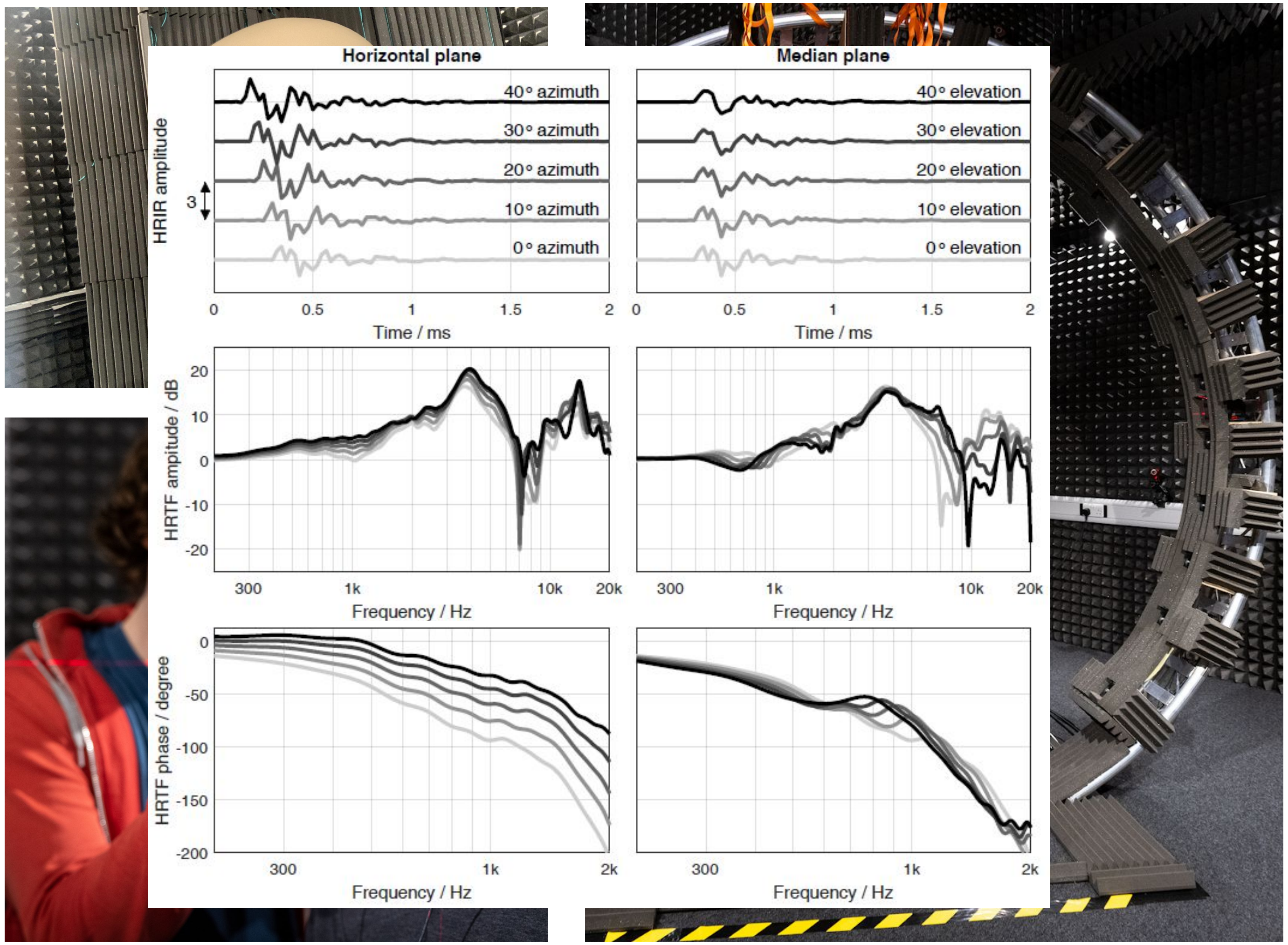
Listener Acoustics
Head-Related Transfer Functions

- **Generic HRTFs** (dummy-head)
  “one fits all”
- **Individual HRTFs**
  - Time-/resource-consuming measurements
  - Special equipment
- **Personalised HRTF**
  - individual HRTFs for everyone are still prohibited.
  - many (too) psychological/neurophysiological/neurological studies relied on generic HRTFs. Are they valid?
  - if personalization is involved, no proper knowledge of the impact of that specific personalization is usually provided
  - discussion/limitation point on the impact of personalization.



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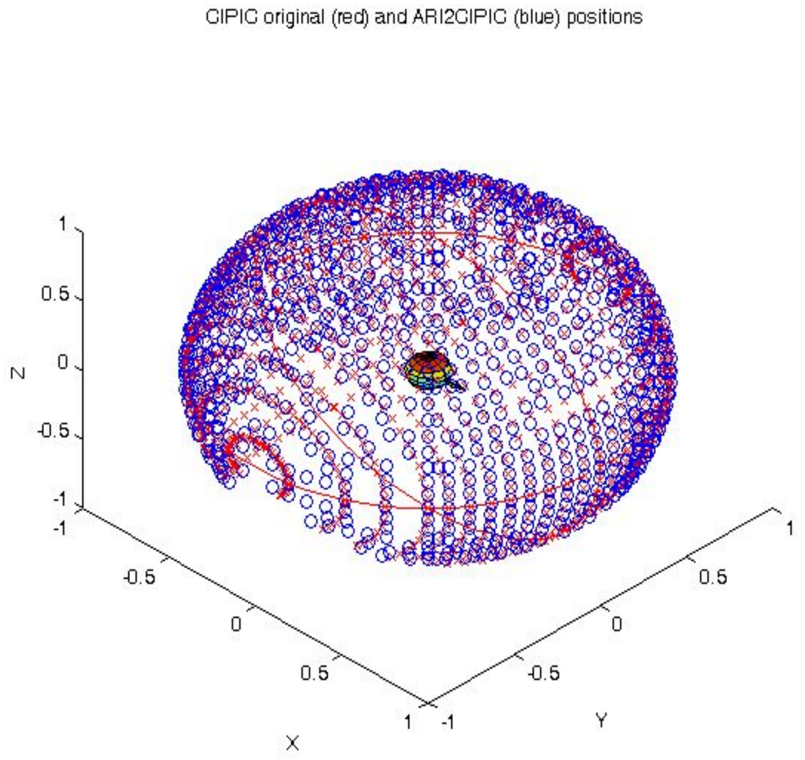
2 Tasks

- **Task 1:** HRTF normalisation for merging different HRTF datasets
- **Task 2:** spatial upsampling for obtaining a high-spatial-resolution HRTF from a very low number of directions



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Task 1

Merging Different HRTF Datasets

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101017743

Task 1 - Recap

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NUMBER OF SUBMISSIONS: 3

TASK: Given a set of HRTFs measured from different individuals in different labs (i.e. different measurement setups, different equipment, different space, and distances, etc.) harmonise the sets to compensate for the influences of the measurement setup.

DATA PROVIDED:
From **8 collections** of free-field compensated HRTFs (HUTUBS, RIEC, SADIE2, 3D3A, SONICOM, SCUT, CHEDAR, Widespread), **ten subjects each** were selected to be used as experiment data for the challenge.

EVALUATION:
Harmonised HRTF datasets of **80 subjects**.

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Task 1 – Validation (stage 1)

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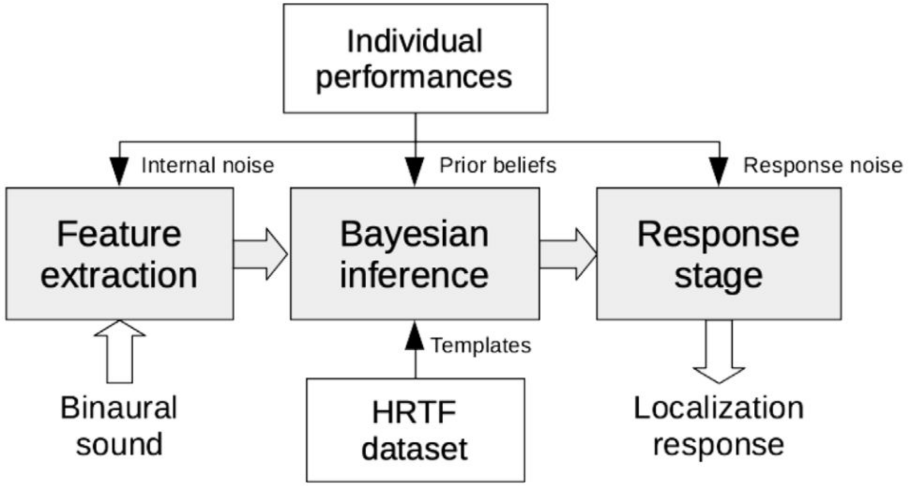
Verify that the submitted ones are indeed HRTFs.

The thresholds are on the differences between the original and harmonised HRTF dataset (same subject), and the output of this stage is binary - it is or is not considered a realistic HRTF.

Thresholds on the output of the auditory model (Barumerli et ., 2023)

- Barumerli2023 is the only available model capable of predicting auditory location over the **entire sphere**
- Thresholds computed on Club Fritz collection (only Neumann KU100 in different measurement setups)
- for at least for 64 of 80 harmonised HRTF datasets (80%) must be inside the thresholds.



Metric		**Threshold**
Accuracy	lateral	5.86 deg
	polar	12.67deg
RMS error	lateral	20.71 deg
	polar	5.90 deg
Quadrant error		34.56 %
Polar gain		0.33 1/deg

R. Barumerli, P. Majdak, M. Geronazzo, D. Meijer, F. Avanzini, and R. Baumgartner, “A Bayesian model for human directional localization of broadband static sound sources,” *Acta Acust.*, vol. 7, p. 12, 2023, doi: 10.1051/aacus/2023006.

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Task 1 – Evaluation (stage 2)

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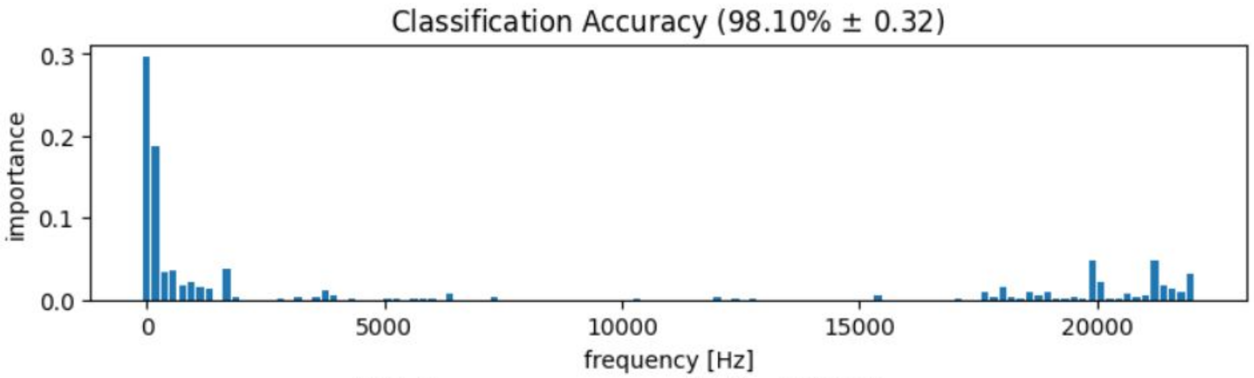
The evaluation employs a classifier (Pauwels and Picinali, 2023) to test to what extent different collections can be distinguished from each other after harmonisation, affirming the removal of measurement setup-induced biases.

The classifier score will be the average accuracy computed through five-fold cross-validation across the collections.

- Averaged over simple CART decision tree and linear support vector machine (SVM) classifier
- The classifier achieved a perfect score of 1 when tested on the original HRTF set
- 0.125 chance level



(b) frequency range 0 Hz–22kHz

J. Pauwels and L. Picinali, "On the Relevance of the Differences Between HRTF Measurement Setups for Machine Learning," in *ICASSP 2023 - 2023 IEEE Int. Conf. Acoustics, Speech and Signal Processing (ICASSP)*, Jun. 2023, pp. 1–5. doi: 10.1109/ICASSP49357.2023.10096689.

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Task 1 – The Winner

Merging Different HRTF Datasets

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Task 1 - Submissions

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Solution	Brief description
IOA3D	A neural network with three blocks with fully connected layers, batch normalization, and ReLU activation. The loss function includes RMS error, spectral distortion, and classification error.
Bahu	(i) Light dynamic compression, (ii) cutting HRIR at a specific time length, and (iii) applying diffuse-field equalization (proprietary)
Arévalo	PCA components per subject, based on localization metrics thresholds or a 95% reconstruction cap

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Task 1 – Ranking summary

Stage 1

IOA3D: 76/80 ✓
Bahu: 72/80 ✓
Arévalo: 69/80 ✓

Stage 2

1- IOA3D: 0.2625
2- Bahu: 0.9125
3- Arévalo: 0.95

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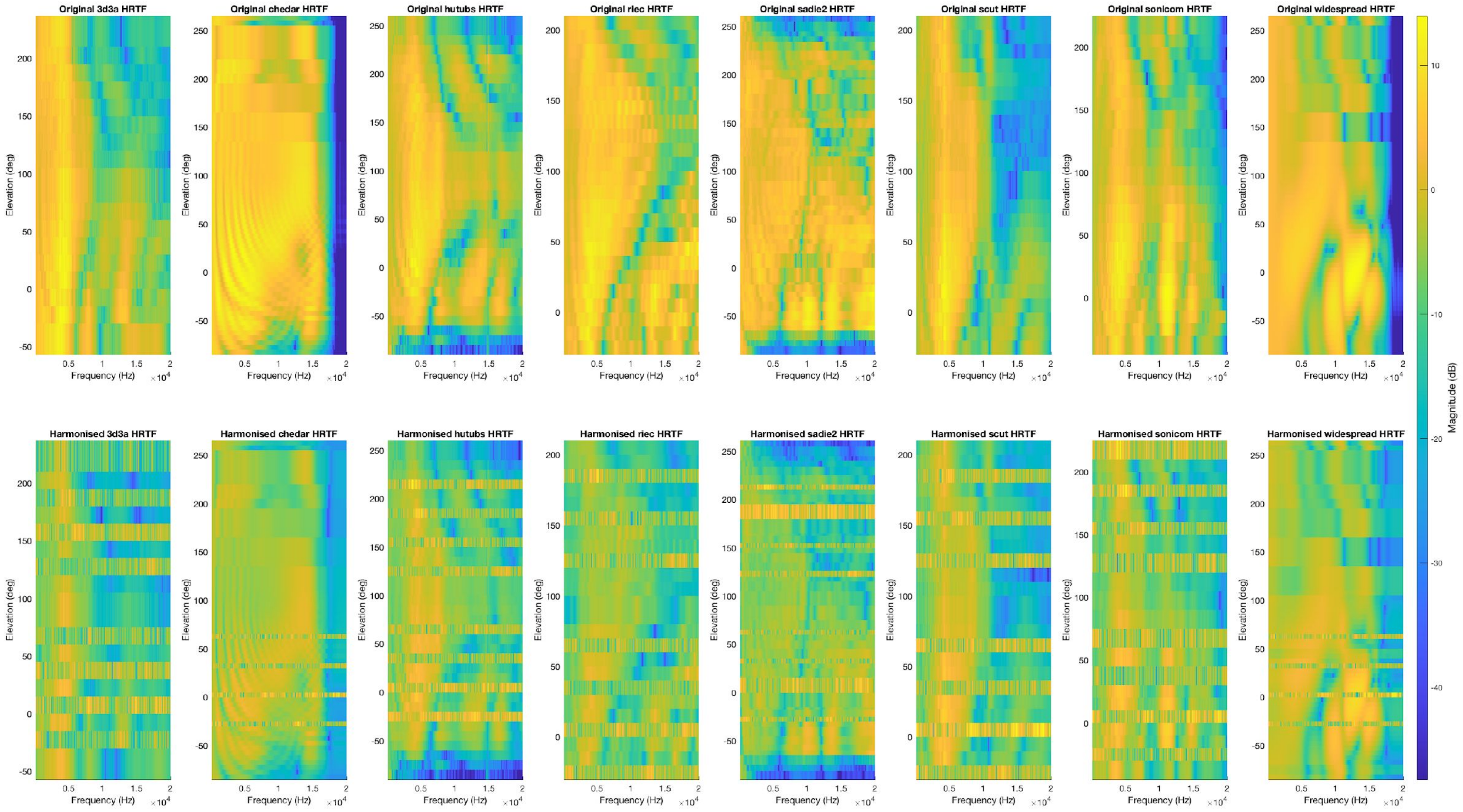
Future challenges in task 1



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Task 2

Spatial Up-sampling of HRTF Sets

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Task 2 - Recap

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NUMBER OF SUBMISSIONS: 8

TASK: Upsampled HRTFs of **12 subjects** to full resolution

DATA PROVIDED:
SONICOM publicly available dataset *(200 subjects)*

SONICOM not publicly available dataset *(12 subjects)*

- 4 sparsity levels (**100**, **19, 5**, and **3** measurement points)
- 3 subjects per sparsity level

EVALUATION:
Full resolution measured HRTFs of the **12 subjects** (**793** positions) not publicly available)

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Task 2 – Validation (stage 1)

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Verify that the 10 out of the 12 submitted HRTFs are within ITD/ILD/LSD thresholds.

The submissions that fail to meet the criteria will be disqualified from further evaluation.

IOA3D	✓	
SYT_FSP-AE	✓	
SUpDEQ_MCA	✓	
GEP-GAN	✓	
Kalimotxo	✓	
UDiPD	✗	ITD issue
MERLI	✓	
MERL 2	✓	
Baseline 1 – Barycentric	✗	levels 3 and 5 – ILD and LSD
Baseline 2 - SH	✗	

Table 1

Feature	**Threshold**
ITD	100 μs
ILD	4.4 dB
LSD	7.4 dB

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Task 2 – Evaluation (stage 2)

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The resulting 12 metrics (three metrics at stage 1 for each of the four sparsity levels) are normalised using a standard score (z-score) based on the distributions for the baseline methods.

The three z-scores at each difficulty level are then summed, and the initial rankings of each submission will be released per difficulty level (from the smallest z-score corresponding to the best performance in the difficulty level).

Finally, the four z-scores will be summed again, and the submission with the lowest total z-score will be declared the final winner of the challenge.

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Task 2 – The Winner

Spatial Up-sampling of HRTF Sets

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Task 2 - Submissions

Solution	Brief description
IOA3D	Convolutional neural network
SYT_FSP-AE	Autoencoder-based neural network
SUpDEQ_MCA	Magnitude-Corrected and Time-Aligned Interpolation
GEP-GAN	Convolutional super-resolution generative adversarial network
Kalimotxo	Autoencoder-based neural network
UDiPD	Psychoacoustically-motivated IIR neural field
MERLI	Retrieval-augmented neural field
MERL 2	Retrieval-augmented neural field (2nd ver)

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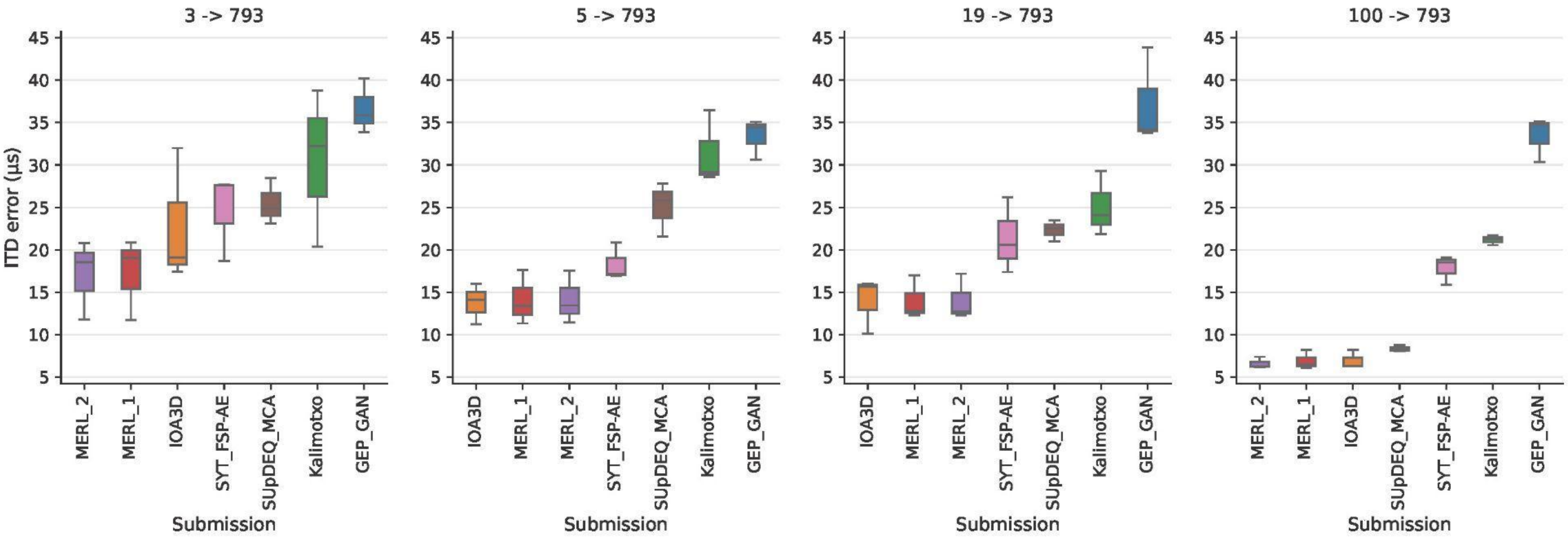
Task 2 – Evaluation (stage 2) - ITD



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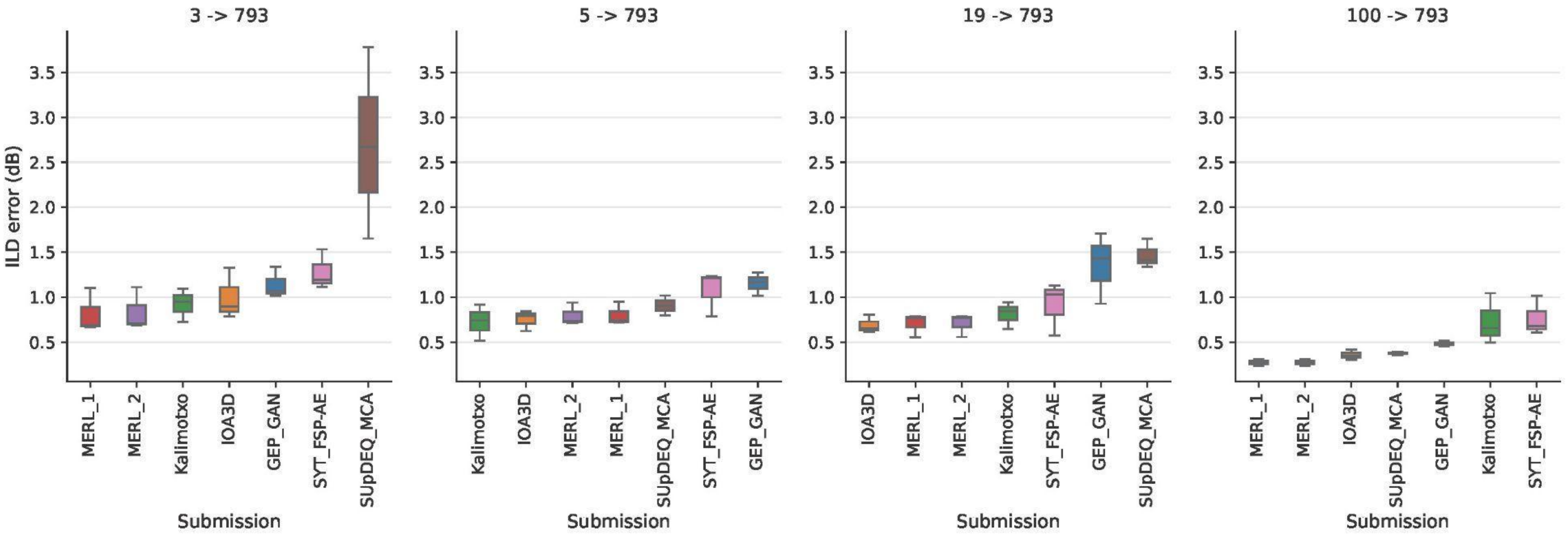
Task 2 – Evaluation (stage 2) - ILD



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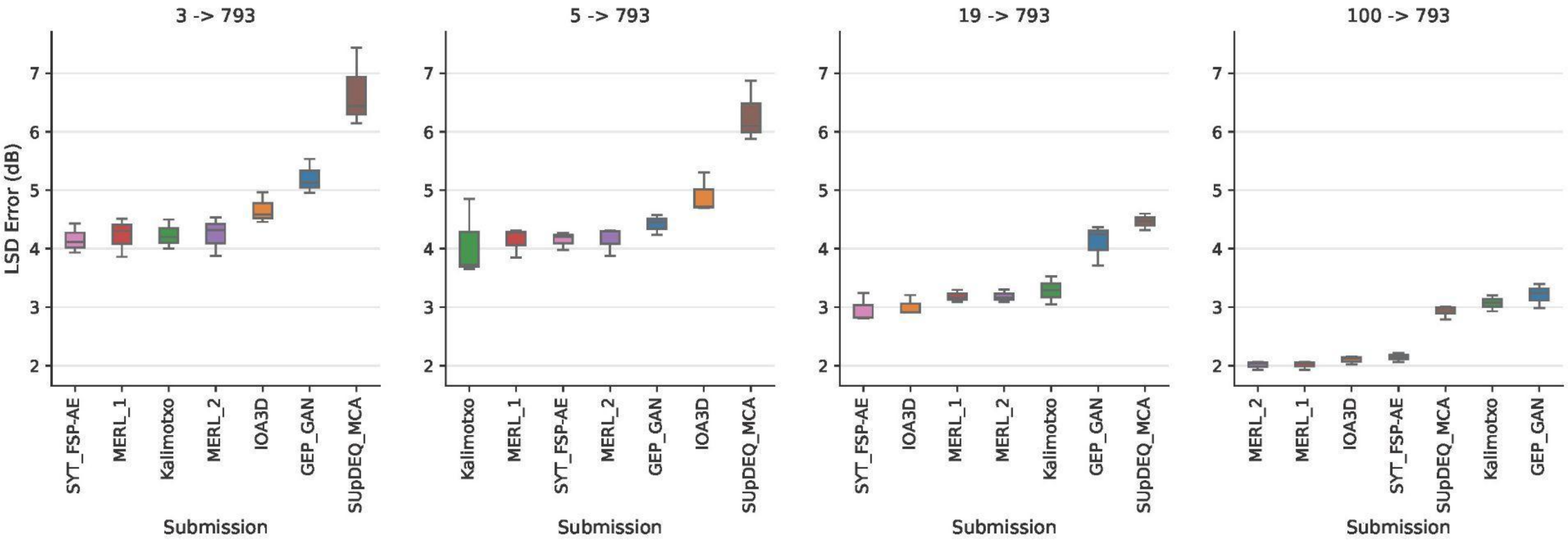
Task 2 – Evaluation (stage 2) - LSD



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Task 2 – Ranking Summary

Sparsity level 3		Sparsity level 5		Sparsity level 19		Sparsity level 100	
model	score	model	score	model	score	model	score
MERL_1	-12.688	MERL_1	-13.329	IOA3D	-14.732	MERL_2	-17.600
MERL_2	-12.674	MERL_2	-13.312	MERL_1	-14.514	MERL_1	-17.543
IOA3D	-11.002	IOA3D	-12.612	MERL_2	-14.510	IOA3D	-17.341
SYT_FSP-AE	-10.922	SYT_FSP-AE	-12.270	SYT_FSP-AE	-13.241	SUpDEQ	-16.165
Kalimotxo	-10.249	Kalimotxo	-10.488	Kalimotxo	-12.353	SYT_FSP-AE	-14.920
GEP_GAN	-7.848	GEP_GAN	-9.264	SUpDEQ	-10.773	Kalimotxo	-13.366
SUpDEQ	-6.360	SUpDEQ	-8.956	GEP_GAN	-8.696	GEP_GAN	-11.372

Ranking Summary for Task 2 submissions

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Task 2 - Winner - MERL 2

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Overall	
model	score
MERL_2	-58.098
MERL_1	-58.075
IOA3D	-55.688
SYT_FSP-AE	-51.355
Kalimotxo	-46.457
SUpDEQ	-42.256
GEP_GAN	-37.182

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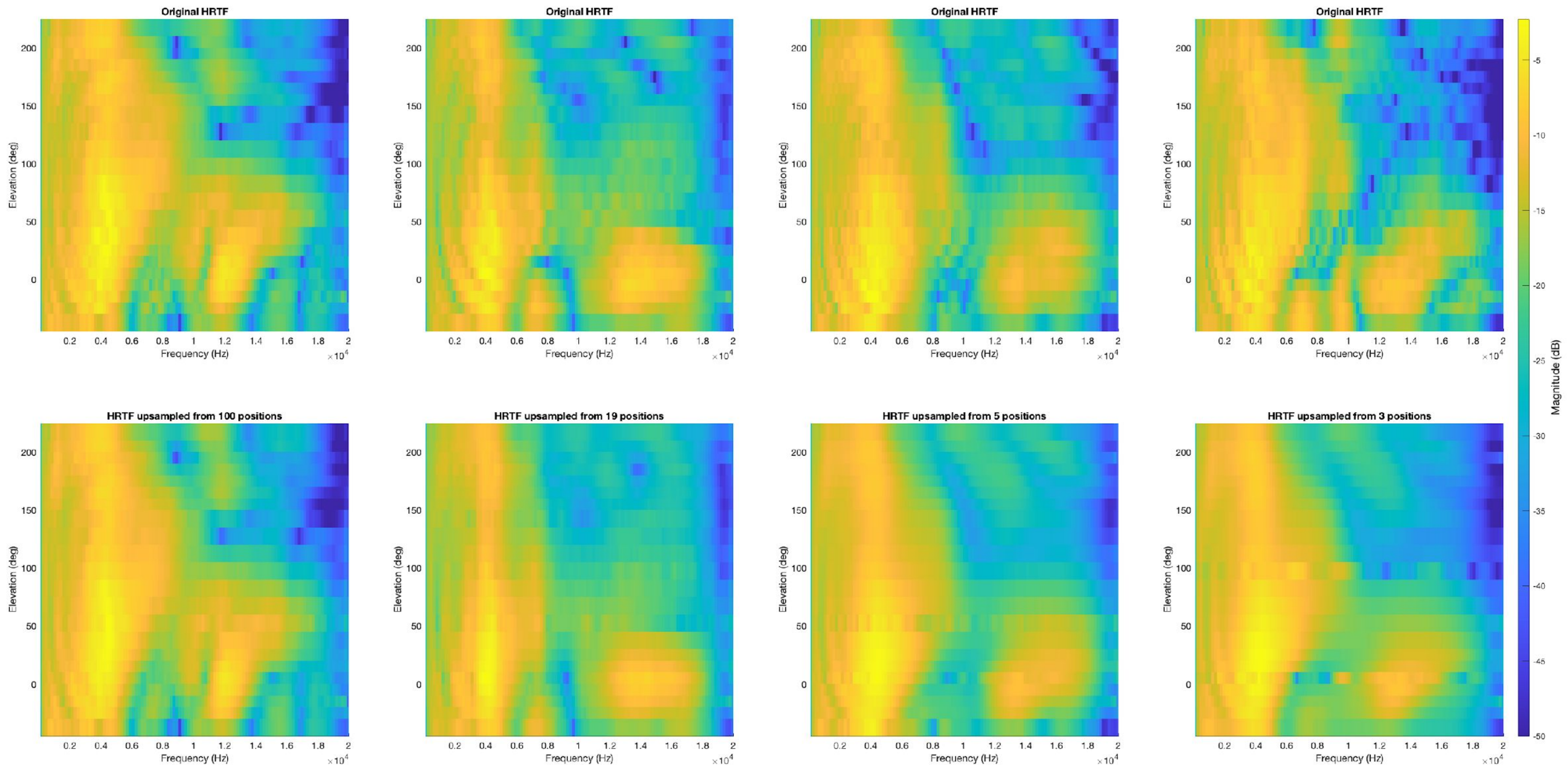
Future challenges in task 2



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Closing

The Award Ceremony

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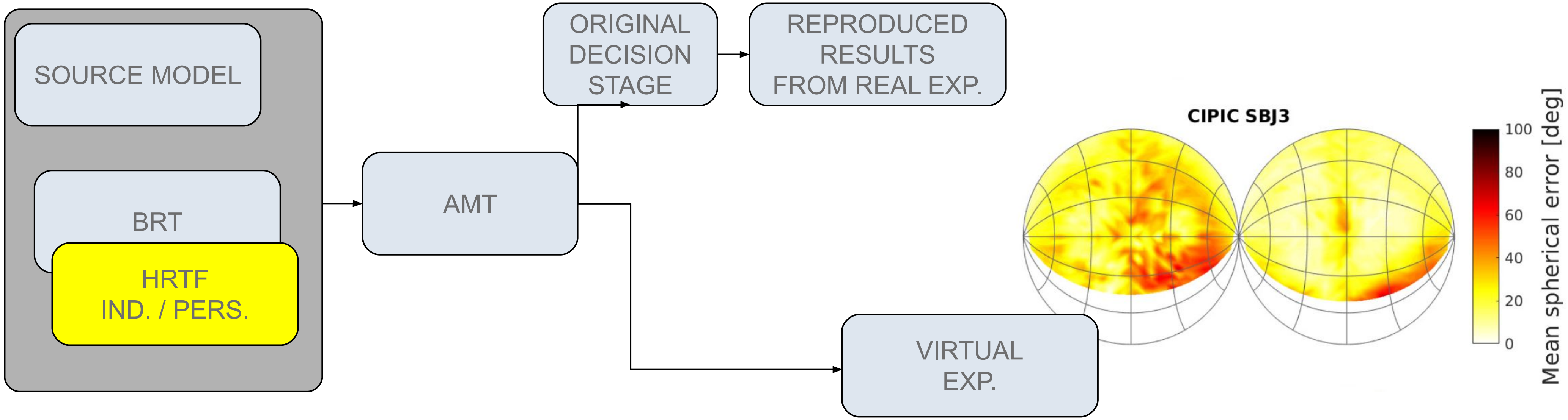
Next steps

- Special issue/topic: **IEEE Open Journal of Signal Processing**
  - Investigate the differences between methods beyond the LAP numbers
  - Structuring the discussions that emerged during the opening phase of submissions: thresholding, metric limitations, classifier use, etc.
- LAP 2025 - New tasks with more aspects: e.g., HRTF personalization and localization, HRTF and user experience, HRTF and room acoustics
  - Inclusion of listening tests, different computational auditory models



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Chairs

Main Chair	Main Co-chair	Implementation Chair	Communication Chair
			
Michele Geronazzo University of Padova	Lorenzo Picinali Imperial College London	Roberto Barumerli University of Verona	Aidan Hogg Queen Mary University of London

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Special Thanks!
The LAP Team

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Glen McLachlan
University of Antwerp

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Relevant URLs, Documents and Resources

SONICOM

LAP Challenge 2024

https://www.sonicom.eu/lap-challenge/

Evaluation Code

https://github.com/Audio-Experience-Design/LAPChallenge

Spatial Audio Metrics library (Python)

https://spatial-audio-metrics.readthedocs.io/en/latest/

Technical Report

https://imperialcollegelondon.app.box.com/s/okuvkjiizrlv761na73ico2ocpqkfn7d

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U))) SOUND

Dreamwaves

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Our solution:
Audio Augmented Reality

"is like a friend is calling you …"

Previous sound point

Dreamwaves

Navigation Technology

Our proposed technology, integrates **hands free navigation** through **spatial audio, augmented reality** and **accurate localization** of the user.

Active sound point

Next sound point

Play demo video


U SOUND
MEMS speakers

Thank You

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UNIVERSITÀ DEGLI STUDI DI MILANO DIPARTIMENTO DI INFORMATICA
Laboratorio di Informatica Musicale
HELLENIC REPUBLIC National and Kapodistrian University of Athens
LabMAT
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University of Glasgow
Dreamwaves
Reactify ADDING NEW DIMENSIONS TO MUSIC
USOUND

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