PROCEEDINGS of the
24th International Congress on Acoustics

October 24 to 28, 2022, in Gyeongju, Korea

Extended abstract

ABS-0852

Evaluation of spatial tasks in virtual acoustic environments by means of modeling individual localization performances

Roberto BARUMERLI[1]; Piotr MAJDAK[1]; Michele GERONAZZO[2]; David MEIJER[1]; Federico AVANZINI[3]; Robert BAUMGARTNER[1]

[1] Acoustic Research Institute, Austrian Academy of Sciences, Austria

[2] Dept. of Management and Engineering, University of Padova, Italy

[3] Dept. of Computer Science, University of Milano, Italy

ABSTRACT

Virtual acoustic environments (VAEs) are an excellent tool in hearing research, especially in the context of investigating spatial-hearing abilities. On the one hand, the development of VAEs requires a solid evaluation, which can be simplified by applying auditory models. On the other hand, VAE research provides data, which can support the further improvement of auditory models. Here, we describe how Bayesian inference can predict listeners' behavior when estimating the spatial direction of a static sound source presented in a VAE experiment. We show which components of the behavioral process are reflected in the model structure. Importantly, we highlight which acoustic cues are important to obtain accurate model predictions of listeners' localization performance in VAE. Moreover, we describe the influence of spatial priors and sensorimotor noise on response behavior. To account for inter-individual differences, we further demonstrate the necessity of individual calibration of sensory noise parameters in addition to the individual acoustic properties captured in head-related transfer functions.

Keywords: sound localization, binaural sounds, probabilistic approach

1 INTRODUCTION

The fidelity of virtual acoustic environments (VAEs) is commonly assessed via psychoacoustic experiments. However, these procedures are usually time-consuming and limited to small sample sizes (1). A more efficient alternative utilizes computational models to evaluate VAEs for a larger population (2). In particular, auditory localization models can be applied to investigate the various attributes of spatial audio quality in VAEs (3). However, models that investigate sound localization are usually limited to either the horizontal (4), vertical (5) or radial (6) dimension while VAEs provide the users with a 3D sound experience.

To overcome this limitation, we here present a Bayesian inference framework that is capable of incorporating multiple spatial features as well as prior knowledge. The probabilistic approach is further designed to accommodate inter-individual differences in perceptual uncertainty with the aim to match the localization performance of a human individual to the best possible degree. Our evaluation of the framework mainly focused on the vertical dimension where inter-individual differences are quite pronounced (7).

[1]roberto.barumerli@oeaw.ac.at

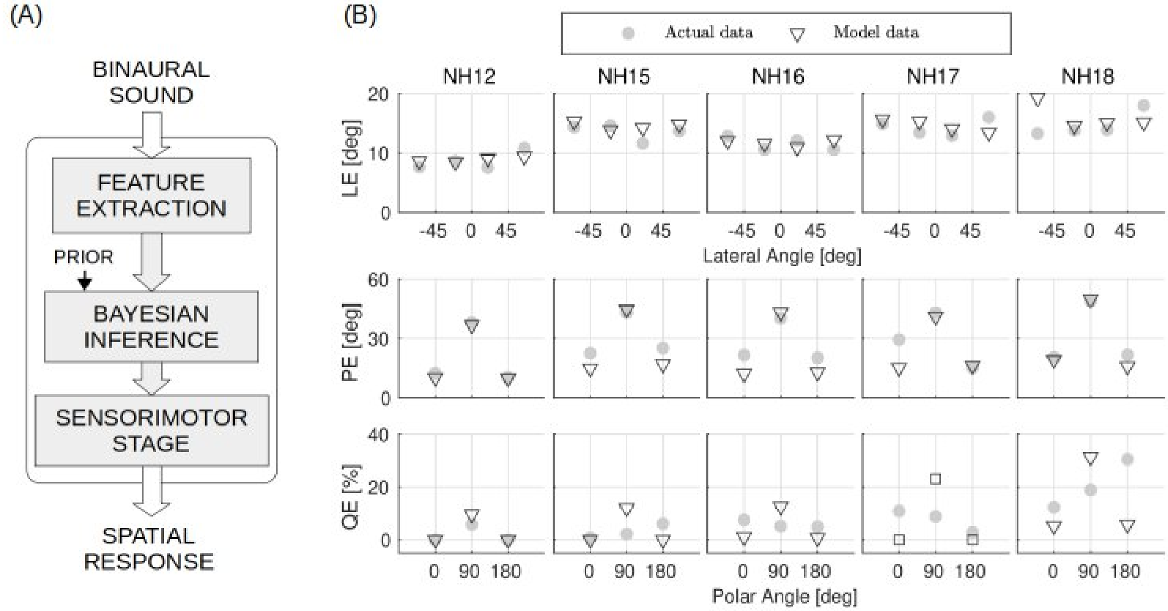

Figure 1: (A) Structure of the Bayesian spatial auditory model framework; (B) direct comparison of subject and model performances in terms of lateral, polar and quadrant errors (LE, PE and QE, respectively) as defined in (1).

2 THE MODEL

The basic structure of the model framework is depicted in Fig. 1A. The model first extracts spatial features such as interaural time differences (ITDs), interaural level differences (ILDs), and monaural spectral-shape cues from the binaural sound. These features are corrupted by additive Gaussian noise with individual variance in order to limit the sensitivity to individual cues. Then, those noisy input features are compared with location-specific templates to obtain a spatial likelihood function. Bayesian inference then combines the likelihood with priors to form a posterior distribution. The maximum of this distribution comprises the optimal choice in a spatial identification task. Finally, a sensorimotor scatter is introduced to predict the listener's spatial pointing response in a localization experiment.

By using gradient extraction to extract monaural spectral-shape cues (6), a very simplistic approach to extract ITDs and ILDs (8), and a persistent spatial prior reducing the likelihood of elevated sources (9), the model can be fitted to listener-specific localization performance reasonably well. Fig. 1B shows results for five listeners and three commonly used performance metrics, evaluating localization accuracy on the horizontal dimension (LE, top row), on the vertical dimension (PE, middle row), and with respect to the frequency of large errors such as front/back confusions (QE, bottom row). While the metrics of good localizers such as NH12 (most left column) can be fitted very well, deviations between actual and simulation results remain especially for poor localizers such as NH18 (most right column).

The model implementation is named as *barumerli2022* in the Auditory Modelling Toolbox (10) and it can be tested by running the script *demo_barumerli2022*.

ACKNOWLEDGEMENTS

This work was supported by the European Union (EU) within the project SONICOM (grant number: 101017743, RIA action of Horizon 2020) and the Austrian Science Fund (FWF) within the project Dynamates (grant number: ZK66).

REFERENCES

1. Majdak P, Goupell MJ, Laback B. 3-D localization of virtual sound sources: Effects of visual

environment, pointing method, and training. Attention, Perception, & Psychophysics. 2010 Feb;72(2):454–69.

2. Geronazzo M, Spagnol S, Avanzini F. Do We Need Individual Head-Related Transfer Functions for Vertical Localization? The Case Study of a Spectral Notch Distance Metric. IEEE ACM Trans Audio Speech Lang Process. 2018 Jul;26(7):1247–60.

3. Lindau A, Erbes V, Lepa S, Maempel HJ, Brinkman F, Weinzierl S. A Spatial Audio Quality Inventory (SAQI). Acta Acustica united with Acustica. 2014 Sep 1;100(5):984–94.

4. Dietz M, Ewert SD, Hohmann V. Auditory model based direction estimation of concurrent speakers from binaural signals. Speech Communication. 2011 May;53(5):592–605.

5. Baumgartner R, Majdak P, Laback B. Modeling sound-source localization in sagittal planes for human listeners. The Journal of the Acoustical Society of America. 2014;136(2):791–802.

6. Baumgartner R, Majdak P. Decision making in auditory externalization perception: model predictions for static conditions. Acta Acust. 2021;5:59.

7. Majdak P, Baumgartner R, Laback B. Acoustic and non-acoustic factors in modeling listener-specific performance of sagittal-plane sound localization. Front Psychol. 2014 Apr 23;5.

8. Xie B. Head-Related Transfer Function and Virtual Auditory Display. Plantatation, FL: J. Ross Publishing; 2013.

9. Ege R, van Opstal AJ, van Wanrooij MM. Accuracy-Precision Trade-off in Human Sound Localisation. Sci Rep. 2018 Dec;8(1):16399.

10. Majdak P, Hollomey C, Baumgartner R. AMT 1.x: A toolbox for reproducible research in auditory modeling. Acta Acust. 2022;6:19.