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Published in:

2014 14th International Workshop on Acoustical Signal Enhancement (IWAENC)

DOI (link to publication from Publisher):

[10.1109/IWAENC.2014.6953334](https://doi.org/10.1109/IWAENC.2014.6953334)

Publication date:

2014

Document Version

Accepted author manuscript, peer reviewed version

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Nielsen, J. K., Jensen, J. R., Jensen, S. H., & Christensen, M. G. (2014). The Single- and Multichannel Audio Recordings Database (SMARD). In *2014 14th International Workshop on Acoustical Signal Enhancement (IWAENC)* (pp. 40-44). IEEE (Institute of Electrical and Electronics Engineers).
<https://doi.org/10.1109/IWAENC.2014.6953334>

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THE SINGLE- AND MULTICHANNEL AUDIO RECORDINGS DATABASE (SMARD)

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ABSTRACT

A new single- and multichannel audio recordings database (SMARD) is presented in this paper. The database contains recordings from a box-shaped listening room for various loudspeaker and array types. The recordings were made for 48 different configurations of three different loudspeakers and four different microphone arrays. In each configuration, 20 different audio segments were played and recorded ranging from simple artificial sounds to polyphonic music. SMARD can be used for testing algorithms developed for numerous application, and we give examples of source localisation results.

Index Terms— Multichannel recordings, audio database, source localisation

1. INTRODUCTION

The processing of single- and multichannel audio recordings is a very active field of research within the signal processing community and important in numerous applications such as noise reduction, echo cancellation, source separation, source localisation, room geometry estimation, distributed array processing, recognition, and de-reverberation [1–11]. Despite the heavy research activities in the field, only a few high quality multichannel audio recordings have been made available online to the research community. Consequently, many of the developed signal processing algorithms are in research papers only evaluated on simulated data (e.g., generated using room impulse response generators [12, 13]), on data of a low quality, or on non-public data, and this might inhibit reproducibility [14], complicate algorithm comparison, or ultimately lead to the wrong conclusions. There are multiple reasons for why it is difficult to obtain good quality audio recordings. For example, making high quality recordings can be very time-consuming; professional measurement equipment is often expensive; dedicated listening rooms, anechoic chambers, and laboratory equipment might not be available; or many external nuisances, which might be hard to eliminate, can influence the quality of the recordings.

To extend the amount of freely available single- and multichannel audio recordings, we here present a new database called the *Single- and Multichannel Audio Recordings Database* (SMARD) which is made freely available online¹. The database contains both single- and multichannel recordings of artificial signals as well as of reverberant and anechoic speech, vocal, and musical signals emitted by various loudspeaker types. The recordings are made with four different microphone arrays in a box-shaped listening room. Moreover, the position of the microphones and loudspeakers inside this room as well as the temperature are also measured. Although useful in many applications, SMARD was compiled for the primary purpose of source localisation and room geometry estimation. For source localisation, SMARD extends databases such as the multi-channel Wall Street journal audio visual corpus (MC-WSJ-AV) [15] and the audio-visual corpus for speaker localization and tracking [16] by using multiple array topologies and other source signals than speech. Moreover, since the microphone and loudspeaker locations relative to the room were also measured, SMARD can also be used for room geometry estimation. Although the data used in [4] have been made available online, SMARD is to the best of our knowledge the first freely available database which can be used for this purpose. For different array structures in different settings, multichannel impulse responses can be found in online available databases². In contrast to these, SMARD contains the raw recordings from which multichannel impulse responses can be estimated if desired.

In this paper, we first describe how the data in SMARD were recorded. Specifically, we describe the listening room, the measurement equipment, and the measurement configurations. Secondly, we give a few examples of source localisation results based on these data.

2. DESCRIPTION OF SMARD

SMARD contains approximately 18 GB of audio recordings at a sampling frequency of 48 kHz. All or a subset of these recordings can be downloaded from the SMARD website.

This work was partially funded by the Danish Council for Independent Research - Grant no.: DFF-1337-00084, the Villum Foundation, and InnovationsFonden.

¹The data can be downloaded at <http://www.smard.es.aau.dk>. If you use SMARD in a peer-reviewed research paper or in a book, we kindly ask you to email us a BibTeX entry which we will publish on the SMARD website.

²See <http://www.commsp.ee.ic.ac.uk/> for a list of these databases.

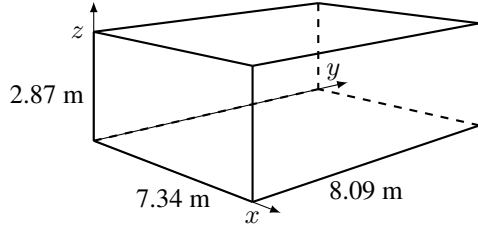


Fig. 1: A sketch of the multi-channel listening room.

Loudspeakers	Brüel & Kjær OmniPower 4296 Brüel & Kjær OmniSource 4295 Custom-made 3" directional loudspeaker
Microphones	G.R.A.S. Prepolarized Free Field Microphone 40AZ G.R.A.S. 26CC Microphone pre-amplifier (dummy) Brüel & Kjær JJ-2617 Coaxial input adapter (51 pF)
Arrays	Single microphone Three 7-element ULAs with 5 cm spacing Two 6-element UCAs with radii of 4 cm and 6 cm Orthogonal array consisting of the three ULAs
A/D Converters	Behringer Ultragrain Pro-8 Digital ADA8000
Sound Card	RME Digi 9652 Project Hammerfall
Power amplifier	Rotel RB-976
Software	Playrec 2.1.0 Portaudio v. 19 20071207 Steinberg ASIO SDK 2.3 MATLAB 2013b

Table 1: Measurement Equipment. More details can be found on the SMARD website.

2.1. The Room

The recordings have all been made in a 60 m² multichannel listening room at Aalborg University, and a sketch of this room is given in Fig. 1. The room is box-shaped, symmetrical, and has an adjustable reverberation time between approximately 0.2 and 0.4 seconds. To increase the amount of reverberation, we removed the carpet on the floor during the measurement campaign.

2.2. Equipment

Recordings were made for various combinations of different loudspeakers and microphone arrays. As detailed in Table 1, three loudspeakers were used. The Brüel & Kjær OmniPower 4296 and the Brüel & Kjær OmniSource 4295 are both approximately omnidirectional loudspeakers within a limited frequency range. The OmniPower 4296 loudspeaker can emit more sound power than the OmniSource 4295, but can only be considered omnidirectional over a narrower frequency range. The directional loudspeaker is a conventional 3" speaker in a wooden cabinet. Pictures of it and its on-axis impulse response can be found on the SMARD website.

Up to 22 G.R.A.S. microphones were used in various array configurations. The simplest array was just a single microphone which can be seen on the right hand side of Fig. 2a. The other array types were uniform linear arrays

Loudspeaker type

- 0XXX OmniPower 4296
- 1XXX OmniPower 4295
- 2XXX Directional loudspeaker

Loudspeaker position and orientation

- X0XX Placed at (2.00, 6.50, 1.25). Angle of -90° in XY -plane
- X1XX Placed at (3.50, 4.50, 1.50). Angle of -45° in XY -plane

Array types

- XX0X Orthogonal array, single microphone, and dummy microphone
- XX1X Three ULAs and dummy microphone
- XX2X Two UCAs, one ULA, and dummy microphone

Array positions and orientations

- XX00 See the SMARD website
- XX01 See the SMARD website
- XX02 See the SMARD website
- XX03 See the SMARD website
- XX10 See the SMARD website
- XX11 See the SMARD website
- XX20 See the SMARD website
- XX21 See the SMARD website

Table 2: The 48 measurement configurations.

Artificial Sounds

- 1 Five seconds of silence
- 2 Exponential sine sweep from 10 Hz to 24 kHz
- 3 Harmonic signals with increasing fundamental frequency in steps
- 4 Eight repetitions of a 16th order MLS sequence
- 5 Pink noise
- 6 Single sinusoidal tone with increasing frequency in steps
- 7 White Gaussian noise

Speech/vocal signals

- 8 Soprano vocal from the EBU SQAM CD
- 9 Quartet vocal from the EBU SQAM CD
- 10 Male voice from the EBU SQAM CD
- 11 Child's voice from the TSP speech database
- 12 Female voice from the TSP speech database
- 13 Male voice from the TSP speech database

Musical signals

- 14 Clarinet from the EBU SQAM CD
- 15 Trumpet from the EBU SQAM CD
- 16 Xylophone from the EBU SQAM CD
- 17 Abba excerpt from the EBU SQAM CD
- 18 Bass flute from the MIS database
- 19 Guitar from the MIS database
- 20 Violin from the MIS database

Table 3: The 20 audio segments.

(ULA) (see Fig. 2c), uniform circular arrays (UCAs) (see Fig. 2d), and an orthogonal array (see Fig. 2b). Finally, a *dummy* microphone, which is simply a capacitor mounted on the microphone pre-amplifier, was also present in all recordings. The recordings from the dummy microphone can be used to inspect electrical noise, cross-talk, etc. Except for the loudspeakers, the microphones, and the arrays, all measurement equipment was situated in a control room adjacent to the multichannel listening room. A list of this equipment can be found in Table 1.

2.3. Measurements Configurations

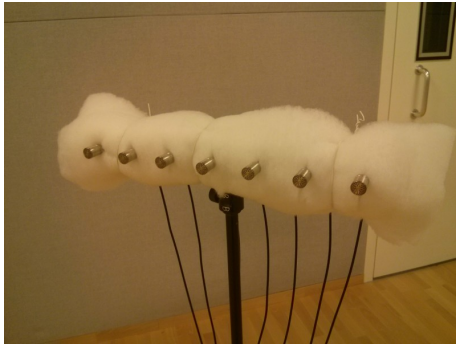
Measurements were made for a total of 48 different configurations. Each configuration is enumerated by a four digit number of the form ABCD where the first and most significant digit A denotes the type of loudspeaker; the second digit B denotes the position and orientation of the loudspeaker; the



(a) Configuration number 0002.



(b) The orthogonal array.



(c) A uniform linear array.



(d) The uniform circular arrays.

Fig. 2: Some pictures of the measurement setup and the arrays.

third digit C denotes the type(s) of microphone arrays; and the least significant digit D denotes the position and orientations of these arrays. Table 2 summarises these configurations and further details can be found on the SMARD website. As an example, Fig. 2a shows a picture of configuration number 0002 which include the OmniPower 4296, the orthogonal array, the single microphone, and the dummy microphone.

2.4. Audio Segments

For each of the 48 configurations, a total of 20 audio segments were played and recorded. As listed in Table 3, seven artificial signals, six speech/vocal signals, and seven musical signals were used. The artificial signals were all created in MATLAB and the code for generating them can be found at the SMARD website. The speech and musical signals consist of both reverberant and anechoic signals. The signals from the EBU SQAM CD [17] are reverberant signals whereas the signals from the TSP speech database [18] and the musical instrument samples (MIS) database [19] are anechoic signals. All of these databases are freely available online³⁴⁵ for research usage.

³EBU SQAM CD: <https://tech.ebu.ch/publications/sqamcd>

⁴TSP speech database:

<http://www-mmssp.ece.mcgill.ca/Documents/Downloads/TSPspeech/>

⁵MIS database: <http://theremin.music.uiowa.edu/MIS.html>

For every configuration, the temperature inside the multi-channel listening room was measured and stored before these 20 audio segments were played. For each of the audio segments, all of the microphone recordings and a loop-back of the loudspeaker signal were stored in the database. A pause of two seconds was added between the segments to ensure that the sound field within the room was stationary before the next segment was played. The first audio segment was just five seconds of silence. The recordings made with this input signal can be used to inspect the stationary acoustical background noise.

3. EXAMPLES OF USE

As previously mentioned, SMARD is useful for evaluating, e.g., noise reduction, localisation, and room geometry estimation algorithms. In this section, we present some results obtained from the evaluation of two localisation algorithms on some of the data in SMARD. The evaluated algorithms are the steered response power with phase transform (SRP-PHAT) method [20], and a near-field, maximum likelihood (ML) method recently proposed in [21]. As the ML method assumes that the desired signal is quasi-periodic, the methods were applied on the synthetic harmonic signals and the violin signals. More specifically, a single segment of 100 samples

		Synthetic						Violin					
Config. no.		2000	2001	2002	2003	2020	2021	2000	2001	2002	2003	2020	2021
True	φ	111.6	111.1	130.2	139.4	108.4	134.8	111.6	111.1	130.2	139.4	108.4	134.8
	ψ	3.1	-2.3	-3.2	2.8	-3.9	2.9	3.1	-2.3	-3.2	2.8	-3.9	2.9
	r_c	5.3	5.3	3.8	5.9	4.6	4.8	5.3	5.3	3.8	5.9	4.6	4.8
SRP-P	φ	112.7	111.8	131.3	141.1	99.1	130.8	112.7	111.1	131.4	140.4	112.5	147.1
	ψ	-0.7	-27.2	-4.4	-22.1	-15.1	15.0	2.6	-1.7	-7.6	-0.4	3.7	4.2
	r_c	4.4	2.8	5.6	2.4	4.3	2.9	6.7	6.7	6.0	7.9	2.8	3.9
ML-AP	φ	111.7	112.1	131.2	140.3	112.8	133.7	112.4	110.9	131.4	139.9	105.8	138.1
	ψ	-0.4	-26.1	-4.8	-20.3	-12.2	14.0	4.3	-1.5	-5.2	0.5	1.7	2.5
	r_c	7.0	3.2	5.2	2.6	6.0	1.6	5.6	3.0	6.1	8.3	6.1	0.4

Table 4: Location estimates in spherical coordinates for different configurations.

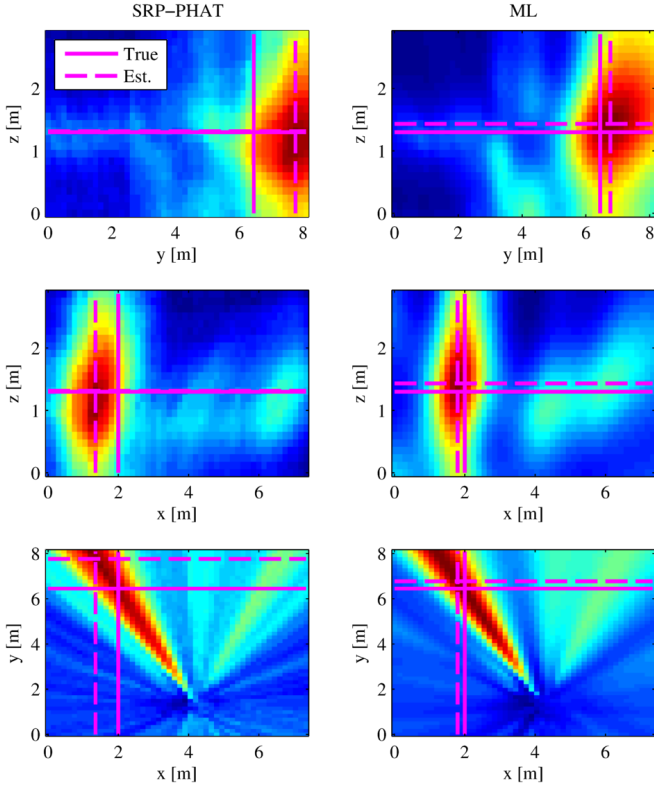


Fig. 3: Cost-functions versus cartesian coordinates for the SRP-PHAT and ML methods when applied on configuration 2000.

was used from each microphone in different configurations. The segment from the harmonic signals was taken from the last part of the signal where the pitch is 500 Hz, while the segment from the violin signals was taken from the first part. The pitch of the signals, which is needed in the ML method, is estimated using the method in [22], and the number of harmonics was assumed known. Further details about the simulation setup can be found on the SMARD website along with the code for running the simulations.

With this simulation setup, we first of all obtained the re-

sults in Figure 3, depicting cost functions and location estimates for the SRP-PHAT and ML methods when applied for localisation of the violin source in configuration 2000. To obtain these plots of the cost functions versus two coordinates at a time, the last coordinate was fixed to the value estimated by the method. We see from the results that the cost functions peak relatively close to the true source position. The methods were also evaluated on other scenarios, yielding the results in Table 4. Generally, the angle (azimuth φ and elevation ψ) estimates are close to the true angles except for a few cases where a strong reflection from the wooden floor dominates the cost functions (configurations 2001 and 2003). The range (r_c) estimates are more inaccurate, but in most cases, the source is also placed relatively far from the arrays. These results supports the potential of applying SMARD for evaluation of, e.g., localisation methods, and the validity of the recorded data.

4. CONCLUSIONS

We have here presented the Single- and Multichannel Audio Recordings Database (SMARD) which can be used for testing algorithms developed for numerous audio signal processing tasks such as source localisation and room geometry estimation. SMARD is made freely available online to facilitate easier testing on real recordings, reproducibility of results, and algorithm comparison based on the same data. The database contains multichannel recordings for 20 audio segments in 48 different configurations arising from using three different loudspeakers, four different microphone arrays, and various source and sensor locations inside a box-shaped listening room.

Acknowledgements

The authors would like to thank Claus Vestergaard Skipper, Martin Bo Møller, Neo Kaplanis, and Peter Skotte for assisting in solving practical problems w.r.t. making the measurements.

5. REFERENCES

- [1] F. Antonacci, J. Filo, M. Thomas, E. Habets, A. Sarti, P. Naylor, and S. Tubaro, "Inference of room geometry from acoustic impulse responses," *IEEE Trans. Audio, Speech, Lang. Process.*, vol. 20, no. 10, pp. 2683–2695, Dec. 2012.
- [2] J. Benesty, J. Chen, and Y. A. Huang, *Microphone array signal processing*, Berlin, Germany: Springer-Verlag, 2008.
- [3] M. Brandstein and D. Ward, *Microphone Arrays: Signal Processing Techniques and Applications*, New York, NY, USA: Springer-Verlag, 2001.
- [4] I. Dokmanić, R. Parhizkar, A. Walther, Y. M. Lu, and M. Vetterli, "Acoustic echoes reveal room shape," *Proc. Natl. Acad. Sci. USA*, vol. 110, no. 30, pp. 1–6, 2013.
- [5] P. A. Naylor and N. D. Gaubitch, *Speech Dereverberation*, Signals and Communication Technology. Springer, 2010.
- [6] J. R. Deller, J. H. L. Hansen, and J. G. Proakis, *Discrete-Time Processing of Speech Signals*, Institute of Electrical and Electronics Engineers, 2000.
- [7] F. Küch and W. Kellermann, *Nonlinear Acoustic Echo Cancellation*, Springer, Heidelberg, Germany, 2006.
- [8] S. Makino, T. W. Lee, and H. Sawada, *Blind Speech Separation*, Signals and Communication Technology. Springer, 2007.
- [9] J. Benesty, M. M. Sondhi, and Y. Huang, Eds., *Springer Handbook of Speech Processing*, Springer-Verlag, 2008.
- [10] A. Bertrand, "Applications and trends in wireless acoustic sensor networks: A signal processing perspective," in *Proc. Symp. Commun., and Veh. Technol.*, Nov. 2011, pp. 1–6.
- [11] R. Heusdens, G. Zhang, R. C. Hendriks, Y. Zeng, and W. B. Kleijn, "Distributed MVDR beamforming for (wireless) microphone networks using message passing," in *Proc. Intl. Workshop Acoust. Echo Noise Control*, Sep. 2012, pp. 1–4.
- [12] E. A. P. Habets, "Room impulse response generator," Tech. Rep., Technische Universiteit Eindhoven, 2010, Ver. 2.0.20100920.
- [13] E. A. Lehmann and A. M. Johansson, "Prediction of energy decay in room impulse responses simulated with an image-source model," *J. Acoust. Soc. Am.*, vol. 124, no. 1, pp. 269–277, Jul. 2008.
- [14] P. Vandewalle, J. Kovacevic, and M. Vetterli, "Reproducible research in signal processing," *IEEE Signal Process. Mag.*, vol. 26, no. 3, pp. 37–47, May 2009.
- [15] M. Lincoln, I. McCowan, J. Vepa, and H. K. Maganti, "The multi-channel wall street journal audio visual corpus (MC-WSJ-AV): Specification and initial experiments," in *Proc. IEEE Workshop on Autom. Speech Recog. and Underst.* IEEE, 2005, pp. 357–362.
- [16] G. Lathoud, J.-M. Odobez, and D. Gatica-Perez, "Av16.3: An audio-visual corpus for speaker localization and tracking," in *Proc. Int. Workshop on Machine Learning for Multimodal Interaction*. 2005, pp. 182–195, Springer.
- [17] European Broadcasting Union, "Sound quality assessment material recordings for subjective tests: Users' handbook for the EBU SQAM CD," Tech. Rep. EBU – TECH 3253, European Broadcasting Union, 2008.
- [18] P. Kabal, "TSP speech database," Tech. Rep., Dept. of Electrical & Computer Engineering, McGill University, 2002.
- [19] L. Fritts, "University of Iowa Musical Instrument Samples," <http://theremin.music.uiowa.edu/>, 1997.
- [20] J. H. DiBiase, H. F. Silverman, and M. S. Brandstein, "Robust localization in reverberant rooms," in *Microphone Arrays - Signal Processing Techniques and Applications*, M. S. Brandstein and D. B. Ward, Eds., chapter 8, pp. 157–180. Springer-Verlag, 2001.
- [21] J. R. Jensen and M. G. Christensen, "Near-field localization of audio: a maximum likelihood approach," in *Proc. European Signal Processing Conf.*, Sep. 2014, submitted.
- [22] J. K. Nielsen, M. G. Christensen, and S. H. Jensen, "Default Bayesian estimation of the fundamental frequency," *IEEE Trans. Audio, Speech, Lang. Process.*, vol. 21, no. 3, pp. 598–610, Mar. 2013.