Research Institute of Electrical Communication
Tohoku University
2-1-1 Katahira, Aoba-ku, Sendai, 980-8577 Japan
✉ salvador@ais.riec.tohoku.ac.jp
cesardsalvador.github.io
scholar.google.com/citations?user=wUJ9TqMAAAAJ
orcid.org/0000-0002-3516-3788
researcherid.com/rid/I-6690-2018
researchgate.net/profile/Cesar_Salvador
linkedin.com/in/cesardsalvador

César D. Salvador

Acoustic Information Science

Date of birth: 9 March 1978.
Nationality: Peruvian.

Resume

I received the Ph.D. and M.Sc. degrees in 2016 and 2013, respectively, both from the Graduate School of Information Sciences, Tohoku University, Sendai, Japan. Currently, I work as an Assistant Professor at the Research Institute of Electrical Communication (RIEC), Tohoku University.

My research on acoustic information science lies at the intersection of theoretical acoustics, array signal processing, human perception, and computational neuroscience. My research focuses on challenges that arise when aiming at the flexible, computationally efficient analysis of auditory scenes, their transmission, and their synthesis with high levels of realism and naturalness. I formulate and design methods for the recording, processing, and reproduction of acoustic environments. Such methods are required, for instance, in machines that yearn to equal the performance of human perception for acoustic environment recognition, in acoustically-transparent devices for hearing aid, in three-dimensional audio installations oriented to large audiences, and in personal audio systems for virtual and augmented reality.

In 2017, I started the research project "Perceptual Constancy in Spatial Hearing". This research aims at contributing to the emergence of future cognitive-based audio processing methods for acoustic environment recognition. To achieve this, patterns of invariability are being identified along databases of morphological and acoustical descriptors of the listeners' external anatomy. This research also aims at establishing mathematical correspondences between the topological index of invariability and the statistical index of connectivity in the auditory brain.

I am seeking opportunities for interdisciplinary collaboration towards the synergic integration of hearing and other modes of perception (e.g., vision and touch). Such integration aims at the devising of a comprehensive framework for multimodal information processing. This framework will enable the creation of multimodal perception systems for robots, human-computer interaction, enhanced hearing aids, immersive environments, and telepresence systems.

Education

2013–2016 **Ph.D., Information Sciences**, *Tohoku University*, Sendai, Japan.

- Doctoral Dissertation: *Binaural Synthesis Based on Spherical Acoustics*
- Advisor: Yôiti Suzuki
- Examiners: Yôiti Suzuki, Shuichi Sakamoto, Akinori Ito, Yoshifumi Kitamura
- Tohoku University Repository: http://hdl.handle.net/10097/00121125

2011–2013 **M.Sc., Information Sciences**, *Tohoku University*, Sendai, Japan.

- Master Thesis: *Binaural Synthesis Based on the Spherical Harmonic Analysis with Compact Microphone Arrays*
- Advisor: Yôiti Suzuki
- Examiners: Yôiti Suzuki, Shuichi Sakamoto, Akinori Ito, Kazuyuki Tanaka
- Tohoku University Repository: http://hdl.handle.net/10097/56638

2005 **B.Sc., Electrical Engineering (Bachiller en Ciencias e Ingeniería, Especialidad Ingeniería Electrónica)**, *Pontifical Catholic University of Peru*, Lima, Peru.

Professional Experience

2017–Present **Assistant Professor (Specially Appointed for Research)**, *Advanced Acoustic Information Systems Laboratory, RIEC, Tohoku University*.

- Start of activities as Principal Investigator of the project "Perceptual Constancy in Spatial Hearing," supported by a Grant-in-Aid of the Japan Society for the Promotion of Science (JSPS), under Grant JP17K12708 (2017–2018). This project aims at the formulation of human-oriented audio processing methods for the identification and localization of sound. Partial results have been reported in a conference paper (see [C4] in my list of publications).
- Continuation of the research activities on physically-motivated high-definition spatial audio, which constitute a sequel to my doctoral and postdoctoral research. The results were published in two journal papers (see [J2,J3] in my list of publications).
- In charge of the international collaboration with Technical University of Dresden and the University of Oldenburg, both in Germany.
- Tutoring of undergraduate and graduate students during their research, teaching of short courses in theoretical acoustics, and organization of exhibitions and demostrations for the annual Open Campus.

2016–2017 **Postdoctoral Researcher**, *Advanced Acoustic Information Systems Laboratory, RIEC, Tohoku University*.

- Formulation of physically-motivated array signal processing methods for high-definition spatial sound systems. Part of these works was a sequel to my doctoral thesis. Results were published in three journal papers (see [J4–J6] in my list of publications).
- Tutoring of undergraduate and graduate students, and teaching of short courses.

2008–2010 **"Docente Investigador", equivalent to Assistant Professor (Research)**, *Faculty of Communication Sciences, University of San Martin de Porres*, Lima, Peru.

- Principal Investigator of the project "Auralization: Towards the authentic representation of sound in space." In this project, spatial sound technologies where applied to the recording, preservation, and reproduction of urban and rural soundscapes of Lima. The results were exhibited annually in the sound art festival "Lima Sonora", and published in four international proceedings (see [C22–C25] in my list of publications).
- Other responsibilities included the teaching of non-credit courses in real-time audio signal processing using Pure Data.

2006–2007 **Academic Coordinator**, *National Institute for Research and Training in Telecommunications (INICTEL)*, Lima, Peru.

- Planning and coordination of workshops in robotics. The workshops were oriented to students of the Army Technical School of Peru and were lectured by INICTEL's academic staff.

2006–2010 **Teaching Assistant**, *Department of Sciences and Engineering, Pontifical Catholic University of Peru*, Lima, Peru.

- Actively involved in the elaboration of experiments and protocols for instruction in the laboratory sessions of the following undergraduate lectures within the specialties of telecommunications and electrical engineering: Communication theory (IEE253, TEL208), Digital signal processing (IEE210, IEE352, TEL233), Microwaves (TEL236), Antenna engineering (TEL345), Computer architecture (IEE208), and Calculus (MAT119).
- I organized and lectured two short courses: Fundamentals of digital audio synthesis and processing (40 hours), and Image processing using matlab (20 hours).
- As a member of the Digital Signal and Image Processing Research Laboratory, I conducted research on real-time digital signal processing with field-programmable gate arrays (FPGAs). One of my challenges was to optimize the channel vocoder effect for computer music by using the wavelet transform. The result was published in an international proceeding (see [C26] in my list of publications).

Awards and Scholarships

2016 **Best Paper Award**, *11th International Conference on Intelligent Information Hiding and Multimedia Signal Processing*, for co-authoring the paper entitled "A compact representation of the head-related transfer function inspired by the wavelet transform on the sphere".

2011–2016 **Scholarship**, *Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT or Monbukagakusho)*, to pursue studies in Graduate School of Information Sciences (GSIS), Tohoku University, Sendai, Japan.

2008 **Scholarship**, *Indian Technical and Economic Cooperation (ITEC)* , to attend a two-months training course on Remote Sensing and Geographical Information Systems at the Indian Institute of Remote Sensing (IIRS), Dehradun, India.

2007 **Honorable Mention**, *UNESCO and Daimler Mondialogo Engineering Award*, for co-authoring a project focused on improving the diagnosis and treatment of tuberculosis and cutaneous Leishmaniasis in Peru using medical imaging techniques, in collaboration with graduate students of the University of Rochester and undergraduate students of the Pontifical Catholic University of Peru.

Research Funding

2017–2018 **Grant-in-Aid for Young Scientists (B)**, *Japan Society for the Promotion of Science (JSPS)*, for the project "Perceptual Constancy in Spatial Hearing", JSPS Grant JP17K12708.
$\approx 35,000$ USD

2018 **Travel Grant**, *European Project Center (EPC), and Institute of Acoustics and Speech Communications (IAS), TU Dresden*, to enable participation in the workshop on the MSC Individual Fellowships Program, with the project "High-definition Acoustic Reconstruction for Multisensory Environments", Dresden, Germany, June 2018.
$\approx 3,000$ USD

2016 **Travel Grant**, *Murata Science Foundation*, to present the paper "Numerical evaluation of binaural synthesis from rigid spherical microphone array recordings" at the Audio Engineering Society International Conference on Headphone Technology, held in Aalborg, Denmark, from Aug. 24th to Aug. 26th, 2016.
$\approx 3,000$ USD

Specialized Fields

Spatial Acoustics Understanding the spatial features of sound that arise from interactions of sound waves with the environment is essential in the development of sound field control technologies. In this field, my interests particularly concern the formulation and validation of accurate sound propagation models under distinct geometrical and physical boundary conditions. For this purpose, I rely on analytic methods of mathematical physics, numerical solutions to the acoustic wave equation, and experimental procedures with microphone and loudspeaker array technology.

Spatial Hearing Before impinging the eardrums, sound waves interact with the listeners' external anatomical shapes, such as their torso, head, and outer ears. The relation between the morphology of individual anatomical shapes and their acoustic filtering properties is viewed by many as holding the key to human spatial hearing and future spatial sound technology for personal use. My research activities in this field include: the construction of databases of morphological and acoustical descriptions of individuals; the modeling of such data along space, frequency, and the individual dimension; and the extraction of features related to generic and individual traits. To this aim, I rely on the following tools: treatment of three-dimensional human models acquired by magnetic resonance imaging and laser scanning, harmonic analysis, point cloud representation by dimensionality reduction, and topological data analysis.

Array Signal Processing The capture, processing, and rendering of spatial sound information involve the simultaneous treatment of multiple signals corresponding to multiple transducers arranged in space. My interests in this field include the formulation of array signal processing methods in abstract domains of representation where it is possible to unmask features that are otherwise hardly observed in the natural spatial domain. Such abstract domains enable the flexible analysis of spatial information and, therefore, the inclusion of low-complexity, optimal routines for array signal processing.

Computational Neuroscience Understanding the computational processes in the human brain that are involved in the sensation, perception, and cognition of sound is essential to contribute to the emergence of human-oriented audio processing methods. As part of the project "Perceptual Constancy in Spatial Hearing", I am reviewing recent models of structural (anatomical links) and functional (statistical association) connectivity that occur in the bottom-up (stimulus-driven) and top-down (task-oriented) neural pathways of the human auditory brain when sound identification and localization tasks are performed. By interpreting the state-of-the-art in auditory brain modeling from a signal processing perspective, recent findings in the fields of neurobiology, cognitive science, complex brain networks, and mathematical neuroscience are being integrated into a comprehensive framework for acoustic environment recognition.

Applied Mathematics The use of mathematical structures and categories to solve practical problems from physics and engineering in turn motivates the development of new mathematical theories. Such new theories then became the subject of study in pure mathematics, where abstract concepts are studied for their own sake. When conducting research in the above-mentioned specialized fields, I am always interested on identifying the invariant structures and categories that underly a problem (e.g., those related to properties that do not depend on the physical and geometrical conditions). The knowledge of such invariants can subsequently be used to generate new methodologies that can potentially be used to solve problems in other specialized fields.

List of Publications

Journal Papers

[J1] S. Hu, J. Treviño, C. D. Salvador, S. Sakamoto, and Y. Suzuki, "Modeling head-related transfer functions with spherical wavelets," *Appl. Acoust.*, vol. 146, pp. 81–88, Mar. 2019.
Available at https://doi.org/10.1016/j.apacoust.2018.10.026
Impact Factor: 1.72

[J2] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Boundary matching filters for spherical microphone and loudspeaker arrays," *IEEE/ACM Trans. Audio, Speech, Language Process.*, vol. 26, no. 3, 461–474, March 2018.
Available at https://doi.org/10.1109/TASLP.2017.2778562
Impact Factor: 2.95

[J3] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Enhancement of spatial sound recordings by adding virtual microphones to spherical microphone arrays," *J. Inf. Hiding and Multimedia. Signal Process.*, vol. 8, no. 6, pp. 1392–1404, Nov. 2017.
Available at http://bit.kuas.edu.tw/∼jihmsp/2017/vol8/JIH-MSP-2017-06-020.pdf
Impact Factor: 1.61

[J4] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Design theory for binaural synthesis: Combining microphone array recordings and head-related transfer function datasets," *Acoust. Sci. Technol.*, vol. 38, no. 2, pp. 51–62, Mar. 2017.
Available at https://doi.org/10.1250/ast.38.51

[J5] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Spatial accuracy of binaural synthesis from rigid spherical microphone array recordings," *Acoust. Sci. Technol.*, vol. 38, no. 1, pp. 23–30, Jan. 2017.
Available at https://doi.org/10.1250/ast.38.23

[J6] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Distance-varying filters to synthesize head-related transfer functions in the horizontal plane from circular boundary values," *Acoust. Sci. Technol.*, vol. 38, no. 1, pp. 1–13, Jan. 2017.
Available at https://doi.org/10.1250/ast.38.1

[J7] S. Hu, J. Treviño, C. D. Salvador, S. Sakamoto, J. Li, and Y. Suzuki, "A local representation of the head-related transfer function," *J. Acoust. Soc. Am.*, vol. 140, no. 3, pp. EL285–EL290, Sept. 2016.
Available at https://doi.org/10.1121/1.4962805
Impact Factor: 1.572

Conference Papers

[C1] F. Monasterolo, S. Sakamoto, C. D. Salvador, Z. Cui, and Y. Suzuki, "The effect of target speech distance on reaction time under multi-talker environment," in *IEICE Tech. Rep.*, vol. 118, no. 313, pp. 83-–88, Nov. 2018.
Available at https://www.ieice.org/ken/index/ieice-techrep-118-312-e.html

[C2] J. Shi, C. D. Salvador, J. Treviño, S. Sakamoto, and Y. Suzuki, "Spherical harmonic representation of rectangular domain sound fields," in *Int. Symp. Universal Acoustical Communication*, Sendai, Japan, Oct. 2018.
Event website http://www.tfc.tohoku.ac.jp/event/4212.html

[C3] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Enhancing binaural reconstruction from rigid circular microphone array recordings by using virtual microphones," in *Proc. Audio Eng. Soc. Int. Conf. Audio for Virtual and Augmented Reality*,

Redmond, WA, USA, Aug. 2018.
Available at http://www.aes.org/e-lib/browse.cfm?elib=19669

[C4] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Dataset of near-distance head-related transfer functions calculated using the boundary element method," in *Proc. Audio Eng. Soc. Int. Conf. Spatial Reproduction —Aesthetics and Science—*, Tokyo, Japan, Aug. 2018.
Available at http://www.aes.org/e-lib/browse.cfm?elib=19602
Dataset available at http://www.ais.riec.tohoku.ac.jp/ salvador/download.html

[C5] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Enhancing the binaural synthesis from spherical microphone array recordings by using virtual microphones," in *IEICE Tech. Rep.*, vol. 117, no. 328, pp. 61–66, Auckland, New Zealand, Nov. 2017.

[C6] H. Sato, W. Arif, S. Sakamoto, C. D. Salvador, J. Treviño, Y. Suzuki, and A. Ito, "A compression method for spherical microphone array recordings using principal component analysis," in *Proc. RISP Int. Workshop on Nonlinear Circuits, Comm. and Signal Process.*, Guam, USA, March 2017.

[C7] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Validity of distance-varying filters for individual HRTFs on the horizontal plane," in *Proc. Spring Meeting Acoust. Soc. Jpn.*, Kawasaki, Japan, March 2017.

[C8] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "A model for spatial sound systems comprising sound field recording, spatial editing, and binaural reproduction," in *IEICE Tech. Rep.*, vol. 116, no. 449, pp. 61–65, Jan. 2017.

[C9] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Sound field interpolation in the spatial domain with a rigid spherical microphone array," presented at *5th Joint Meeting of the Acoustical Society of America and Acoustical Society of Japan*, Dec. 2016.

[C10] J. Treviño, C. D. Salvador, V. Braciulis, S. Sakamoto, Y. Suzuki, K. Yoshikawa, T. Yamasaki, and K. Kidokoro, "Sound source separation in complex environments using an array-of-arrays microphone system," in *Proc. 22nd Int. Cong. Acoust.*, Buenos Aires, Sept. 2016.
Available at http://www.ica2016.org.ar/ica2016proceedings/ica2016/ICA2016-0415.pdf

[C11] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Evaluation of white noise gain in a binaural system for microphone arrays," in *Proc. Autumn Meeting Acoust. Soc. Jpn.*, Toyama, Japan, pp. 401–404, Oct. 2016.

[C12] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Numerical evaluation of binaural synthesis from rigid spherical microphone array recordings," in *Proc. Audio Eng. Soc. Int. Conf. Headphone Technology*, Aalborg, Denmark, Aug. 2016.
Available at https://doi.org/10.17743/aesconf.2016.978-1-942220-09-1

[C13] H. Sato, W. Arif, S. Sakamoto, C. D. Salvador, J. Treviño, and Y. Suzuki, "Compression of spherical microphone array recordings using eigenvalue decomposition," in *Proc. RISP Int. Workshop on Nonlinear Circuits, Comm. and Signal Process.*, Guam, USA, March 2016.

[C14] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "A new signal processing procedure for stable distance manipulation of circular HRTFs on the horizontal plane," in *Proc. Spring Meeting Acoust. Soc. Jpn.*, Yokohama, Japan, pp. 561–564, March 2016.

[C15] J. Treviño, S. Hu, C. D. Salvador, S. Sakamoto, J. Li, and Y. Suzuki, "A compact representation of the head-related transfer function inspired by the wavelet transform on the sphere," in *Proc. Int. Conf. Intell. Inf. Hiding and Multimedia Signal Process. (IIH-MSP)*, Sept. 2015, pp. 372–375.
Available at https://doi.org/10.1109/IIH-MSP.2015.108
Best Paper Award.

[C16] S. Sakamoto, A. Wicaksono, J. Treviño, C. D. Salvador, and Y. Suzuki, "Prediction method for compression of spherical microphone array signals using geometric information," in *Proc. Int. Conf. Intell. Inf. Hiding and Multimedia Signal Process. (IIH-MSP)*, Sept. 2015, pp. 376–379.
Available at https://doi.org/10.1109/IIH-MSP.2015.91

[C17] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Embedding distance information in binaural renderings of far field recordings," in *Proc. EAA Joint Symposium on Auralization and Ambisonics*, Berlin, Germany, April 2014, pp. 133–139.
Available at https://doi.org/10.14279/depositonce-22

[C18] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "Editing distance information in compact microphone array recordings for its binaural rendering," in *IEICE Tech. Rep.*, vol. 114, no. 3, pp. 13–18, Apr. 2014.

[C19] C. D. Salvador, S. Sakamoto, J. Treviño, J. Li, Y. Yan, and Y. Suzuki, "Accuracy of head-related transfer functions synthesized with spherical microphone arrays," *Proc. Mtgs. Acoust.*, vol. 19, no. 1, Apr. 2013.
Available at https://doi.org/10.1121/1.4800833

[C20] C. D. Salvador, S. Sakamoto, J. Treviño, and Y. Suzuki, "A method to synthesize head-related transfer functions based on the spherical harmonic decomposition," in *Proc. Spring Meeting Acoust. Soc. Jpn.*, Tokyo, Japan, pp. 889–892, March 2013.

[C21] J. Treviño, T. Okamoto, C. D. Salvador, Y. Iwaya, Z. Cui, S. Sakamoto, and Y. Suzuki, "High-order ambisonics auditory displays for the scalable presentation of immersive 3D audio-visual contents," in *Proc. 23rd Int. Conf. Artificial Reality and Telexistence*, Tokyo, Japan, 2013.

[C22] C. D. Salvador, "Discrete driving functions for horizontal reproduction using wave field synthesis and higher order ambisonics," in *Proc. Audio Eng. Soc. 129 Convention*, San Francisco, USA, Nov. 2010.
Available at http://www.aes.org/e-lib/browse.cfm?elib=15666

[C23] C. D. Salvador, "Wave field synthesis using fractional order systems and fractional delays," in *Proc. 128th Audio Eng. Soc. Convention*, London, UK, May 2010.
Available at http://www.aes.org/e-lib/browse.cfm?elib=15419

[C24] C. D. Salvador, "A virtual acoustic environment as auditory display front-end for sonification," in *Proc. Interactive Sonification Workshop on Human Interaction with Auditory Displays*, Stockholm, Sweeden, April 2010, pp. 69–72.
Available at https://pub.uni-bielefeld.de/publication/2277223

[C25] C. D. Salvador, "A discretization of the wave field synthesis method for auralization of natural sounds," in *Proc. Int. Multi-Conference on Complexity, Informatics and Cybernetics*, Orlando, FL, USA, April 2010.
Available at
http://www.iiis.org/CDs2010/CD2010IMC/IMCIC_2010/index.asp?id=0&area=5

[C26] C. D. Salvador, "A channel vocoder using wavelet packets on a reconfigurable device," in *Proc. 124th Audio Eng. Soc. Convention*, Amsterdam, The Netherlands, May 2008. Available at http://www.aes.org/e-lib/browse.cfm?elib=14546

Patents

[P1] Y. Suzuki, S. Sakamoto, J. Treviño, C. D. Salvador, and T. Kudo, "Method, program, and device for stereophonic sound reproduction," Japanese Patent Application No. 2016-202494, Oct. 2016.

Professional Affiliations

Member **Institute of Electrical and Electronics Engineers (IEEE), IEEE Signal Processing Society**.

Member **Audio Engineering Society (AES)**.

Member **Acoustical Society of Japan (ASJ)**.

Academic Service

Reviewer **IEEE/ACM Transactions on Audio, Speech, and Language Processing**.

Reviewer **Journal of Information Hiding and Multimedia Signal Processing**.

Administration

2018 **Organizer**, *Exchange Meetings on Spatial Sound, Speech, and Haptic Signal Processing between the Technische Universität Dresden (TU Dresden) and Tohoku University*, held at the Institute of Acoustics and Speech Communication, TU Dresden, Germany, from January 30 to February 2nd, 2018.

2018 **Organizer**, *Exchange Meeting on Spatial Sound and Speech Signal Processing between the Carl von Ossietzky University of Oldenburg and Tohoku University*, held at the Research Group on Auditory Signal Processing for Hearing Devices of the Carl von Ossietzky University of Oldenburg, Germany, on January 29th, 2018.

2017, 2018 **Collaborator**, *Open Campus of Tohoku University, and Open Campus of RIEC*, in charge of the exhibitions of the the Acoustic Information Systems Laboratory, held in July and October.

Languages

- Spanish · Mother tongue
- English · Fluent
- Japanese · Advanced
- French · Advanced

References

References available upon request.