

César D. Salvador, Ph.D.

Acoustic Information Sciences

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Date of birth: 9 March 1978.

Nationality: Peruvian.

Resume

My research interests include spatial hearing and its integration with other modes of perception such as vision and touch. I received the M.Sc. and Ph.D. degrees in 2013 and 2016, respectively, both from the Graduate School of Information Sciences (GSIS), Tohoku University, Sendai, Japan. From April 2017 to March 2019, I worked as an Assistant Professor at the Research Institute of Electrical Communication (RIEC), Tohoku University. From August 2019 to January 2021, I worked as Chief Audio Scientist for Silicon Integrated Co. Ltd., Wuhan, China. In August 2019, I founded Perception Research in Lima, Peru, to foster education and research on spatial acoustics in the context of multisensory perception, artificial intelligence, and immersive technology.

Education

- 2016 **Ph.D., Information Sciences**, *Tohoku University*, Sendai, Japan.
 - Doctoral Dissertation: *Binaural Synthesis Based on Spherical Acoustics*
 - Tohoku University Repository: <http://hdl.handle.net/10097/00121125>
- 2013 **M.Sc., Information Sciences**, *Tohoku University*, Sendai, Japan.
 - Master Thesis: *Binaural Synthesis Based on the Spherical Harmonic Analysis with Compact Microphone Arrays*
 - Tohoku University Repository: <http://hdl.handle.net/10097/56638>
- 2008 **Training**, *Indian Institute of Remote Sensing*, Dehradun, India.
- 2005 **B.Sc., Electrical Engineering (Bachiller en Ciencias e Ingeniería, Especialidad Ingeniería Electrónica)**, *Pontifical Catholic University of Peru*, Lima, Peru.

Professional Experience

- 2019–Present **Founder**, *Perception Research*, Lima, Peru.
 - The Perception team conducts research on acoustics in the context of multisensory perception, artificial intelligence, and immersive technologies. We promote academy-industry cooperation and international collaborations. We also foster the growth of the Spanish-speaking acoustic research community through training and publishing.
- 2019–2021 **Chief Audio Scientist**, *Silicon Integrated Co., Ltd.*, Wuhan, Hubei, China.
 - The audio algorithm development team of Silicon Integrated (SI) in China and Peru creates smart 3D audio solutions for mobile platforms considering immersive user experiences through multisensory interfaces.

- 2017–2019 **Assistant Professor (Specially Appointed for Research)**, *Advanced Acoustic Information Systems Laboratory, RIEC, Tohoku University*.
- 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).
Report available at: <https://kaken.nii.ac.jp/grant/KAKENHI-PROJECT-17K12708>.
 - Research activities on physically-motivated high-definition spatial audio, which constituted a sequel to my doctoral and postdoctoral research. The results were published in two journal papers.
 - 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 demonstrations 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.
 - 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 were 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.
 - 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.

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.
Report available at: <https://kaken.nii.ac.jp/grant/KAKENHI-PROJECT-17K12708>
- 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.
- 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.

Patents

1. Y. Suzuki, S. Sakamoto, J. Treviño, C. D. Salvador, and T. Kudo, “Method, program, and device for stereophonic sound reproduction,” *J-PlatPat*, Japanese Patent Number JP.6556682.B., August 2019.
Available at J-PlatPat

Journal Articles

8. J. Shi, C. D. Salvador, J. Treviño, S. Sakamoto, and Y. Suzuki, “Spherical harmonic representation of rectangular domain sound fields,” *Acoust. Sci. Technol.*, vol. 41, no. 1, pp. 451–453, Jan. 2020.
Available at <https://doi.org/10.1250/ast.41.451>
7. 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>
6. 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>
5. 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>
4. 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>
 3. 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>
 2. 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>
 1. 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>

Conference Papers

35. A. Campos, S. Sakamoto, and C. D. Salvador, “Directional early-to-late energy ratios to quantify intelligibility: A case study in a large auditorium,” *Proc. Int. Conf. Immersive and 3D Audio (I3DA)*, Bologna, Italy, September 2021. Available at <https://doi.org/10.1109/I3DA48870.2021.9610935>
34. A. Urviola, S. Sakamoto, and C. D. Salvador, “Ear centering for near-distance head-related transfer functions,” *Proc. Int. Conf. Immersive and 3D Audio (I3DA)*, Bologna, Italy, September 2021. Available at <https://doi.org/10.1109/I3DA48870.2021.9610891>
33. J. Alarcón, J. Solis, and C. D. Salvador, “Regularized spherical Fourier transform for room impulse response interpolation,” *Proc. IEEE XXVII Int. Conf. Electronics, Electrical Engineering, and Computing (INTERCON)*, Lima, Peru, August 2021. Available at <https://doi.org/10.1109/INTERCON52678.2021.9532805>
32. C. Peng, Y. Shi, B. Yan, L. Wu, Z. Chen, C. D. Salvador and D. Liu, “Power-based thermal limits for micro-speaker protection algorithms,” in *148th Audio Eng. Soc. Convention*, Vienna, Austria, June 2020. Available at <http://www.aes.org/e-lib/browse.cfm?elib=20832>.
31. S. Sakamoto, F. Monasterolo, C. D. Salvador, Z. Cui, and Y. Suzuki, “Effects of target speech distance on auditory spatial attention in noisy environments,” in *Proc. ICA 2019 and EAA Euroregion*, pp. 2177–2181, Aachen, Germany, Sept. 2019. Available at <http://pub.dega-akustik.de/ICA2019/data/articles/001087.pdf>.
30. S. Sakamoto, C. D. Salvador, J. Treviño, and Y. Suzuki, “Binaural synthesis using a spherical microphone array based on the solution to an inverse problem,” in *Proc. Inter-Noise*, pp. 735–738, Madrid, Spain, June 2019.
29. F. Monasterolo, S. Sakamoto, C. D. Salvador, Z. Cui, and Y. Suzuki, “The effect of target speech distance on spatial auditory attention under multi-talker environment,” in *Proc. Spring Meeting Acoust. Soc. Jpn.*, pp. 735–738, Tokyo, Japan, March 2019.

28. C. D. Salvador, R. Teraoka, Y.-W. Liu, M. Sato, A. Kral, and S. Sakamoto, "Computational models of the auditory brain," in *6th Int. Symp. Brainware LSI*, Sendai, Japan, March 2019.
27. 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.
26. 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.
25. 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>
24. 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>
23. 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.
22. 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.
21. 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.
20. 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.
19. 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.
18. 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>
17. 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.

16. 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>
15. 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.
14. 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.
13. 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>
12. 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>
11. 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>
10. 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.
9. 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>
8. 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.
7. 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.
6. 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>
5. 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>

4. 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>
3. 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
2. 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>
1. C. D. Salvador, “Operadores integrales y sus aplicaciones al procesamiento digital de señales,” in *Proc. XXIV Coloquio de la Sociedad Matemática Peruana*, Ica, Peru, June 2006.
Available at [cesardsalvador.github.io/doc/Salvador2006OperadoresIntegralesAplicacionDSP.pdf](https://github.com/cesardsalvador/OperadoresIntegralesAplicacionDSP)

Professional Affiliations

- Member **Institute of Electrical and Electronics Engineers (IEEE).**
- Member **IEEE Signal Processing Society.**
- Member **IEEE Brain Community.**
- Member **Audio Engineering Society (AES).**
- Member **Acoustical Society of Japan (ASJ).**
- Member **American Mathematical Society (AMS).**

Academic Service

- Reviewer **IEEE/ACM Transactions on Audio, Speech, and Language Processing.**
- Reviewer **IEEE Access.**
- Reviewer **The Journal of the Acoustical Society of America.**
- Reviewer **Applied Acoustics.**
- Reviewer **Acoustics Australia.**
- Reviewer **Acoustical Science and Technology.**
- Reviewer **Journal of Information Hiding and Multimedia Signal Processing.**
- Reviewer **2019 AES Conference on Headphone Technology.**
- Reviewer **2020 AES Conference on Audio for Virtual and Augmented Reality.**
- Reviewer **2021 IEEE INTERCON.**
- Reviewer **2021 IEEE EIRCON.**

Administration

- 2019 **Organizer**, *Spatial Acoustics and Hearing Research Week (in Spanish)*, held at Universidad de San Martín de Porres and Centro Fundación Telefónica, from January 28 to February 3, 2019.
Report available at: <https://cesardsalvador.github.io/a3d/>
- 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 2, 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 29, 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.