



# Centre for Acoustic Signal Processing Research (CASPR)

December 2017

The Centre for Acoustic Signal Processing Research (CASPR) is a research centre at the Section for Signal and Information Processing, Department of Electronic Systems, Aalborg University, Denmark. CASPR is supported by the Oticon Foundation, Oticon A/S, and Aalborg University.





Participants at the CASPR Winter School on Signal Processing for Hearing Assistive Devices, AAU, Nov. 2017.

Department of Electronic Systems Signal and Information Processing Section Aalborg University

## **Research in CASPR**

CASPR is conducting research related to advanced statistical signal processing solutions for assistive listening. The research finds direct use in communication devices such as hearing aids, helmets, headphones, cochlear implants, ear monitor, ear pieces, diagnostic equipment, etc. However, the envisioned research also finds use in related areas such as robust speech/speaker recognition, brain computer interfaces, acoustic event detection, etc.

The scientific scope of CASPR encompasses

- statistical signal processing.
- machine learning.
- information and communication theory with applications to wireless exchange of information between listening devices and other external devices.
- pattern recognition.
- data mining in body worn sensor data.
- perception-based statistical signal processing.

CASPR will navigate in a rapidly changing technological landscape: we envision a near future, where the technological landscape allows very different, and better, hearing assistive devices than are known today. Specifically, we envision that near-future hearing assistive devices will:

- increase the wireless exchange of information with each other, with other body-worn devices and with devices outside the body.
- make use of additional microphones on or outside the body, and will employ other types of body-worn or outside-the-body sensors.
- work in a much closer symbiosis with the user.

#### Machine Learning

- Deep neural networks
- Automatic speech recognition
- Multimodal biometrics
- Brain-computer interfaces
- Big Data

Processing

Speech processing

Multi-modal signal

Spatial signal processing

Signals in noise

processing

Data mining

## Statistical Signal

- Wireless sensor networks
  Network coding
  - Data compression

Information and

- Channel coding
- Information flows in systems

**Communication Theory** 

#### Signal Processing and Perception

- Signal processing that
- compensates the auditory system
- Signal processing that complements the auditory system

The scientific disciplines of CASPR



## **Teaching in CASPR**

#### Current courses related to CASPR

CASPR is heavily involved in teaching at B.Sc., M.Sc., PhD., and Postdoc level in disciplines that are relevant to the scientific scope of CASPR:

- Machine Learning (Master and PhD courses), Fall+Spring, 2017.
- Deep Learning (PhD course), Spring 2017.
- Information Theory (Master and PhD courses), Fall 2017.
- Array Processing (Master course) Fall 2017.
- Optimization (Master and PhD courses), Fall 2017.
- Signal Proc. for Hearing Assistive Devices (Phd course), Fall 2017.

CASPR is currently involved in eight student project (see pictures):



Spoken Language Identification".

Thomas R. Hansen, Mathias B. Pedersen, Hoza B. Maniragaba. Project on "Convolution Framelets for Audio Denoising". Mathematical Engineering, 9th Semester.





Søren Skov. Project on "Indoor Visual Navigation using Deep Reinforcement Learning". Mathematical Engineering, long thesis project.

Andrea L. Coifman, Péter Rohoska. Project on "What are the users doing? An exploration of contextual features in the home". Vision, Graphics and Interactive Systems, long thesis project with Bang & Olufsen.





Poul Hoang. Project on "Adaptive Sound Zones". Signal Processing and Computing, 9th Semester project with Bang & Olufsen.

Morten Ø. Nielsen, Barbara Martinovic, Sanne D. Nielsen. Project on "Data Compression in Feed-forward Neural Networks". Mathematical Engineering, 7th Semester project with Oticon. Group 790.



Andreas J. Fuglsig, Kasper Ramsgaard-Jensen, Kristoffer Stern, Julius Garde. Project on "Information Theory in Deep Neural Networks". Mathematical Engineering, 7th Semester. Group 791.



## Winter School Signal Processing for Hearing Assistive Devices

On November 6.-10., 2017, CASPR organized a Winter School on Signal Processing for Hearing Assistive Devices.

The school hosted 36 partipants; 17 from the Danish sound industry and 19 PhD students and postdocs from European universities.

The school consisted of invited lectures given by international experts, lectures by CASPR staff, and theoretical/practical exercises.

The school received additional support from The Thomas B. Thriges Fond.



Prof. Jesper Jensen introduces Matlab practical exercises at the CASPR Winter School.

The school covered four scientific topic areas:

- 1. Introduction to auditory perception (normal and impaired hearing) and a discussion of the basic principles of hearing assistive devices.
- 2. Basic signal processing problems encountered in hearing assistive devices, and in-depth treatment of state-ofthe-art solutions; beamforming and noise reduction, dereverberation, feedback cancellation, hearing loss compensation, etc.

Methodologies for evaluating hearing assistive devices with a particular focus on methods for intelligibility assessment and estimation.

- Cochlear implants and diagnostic methods, e.g., methods for screening of hearing in newborns.
- Emerging technologies for hearing assistive devices, including machine-learning techniques for speech denoising, and signal processing techniques using the emerging wireless infrastructure.



Participants engaged in discussions during one of the breaks.

Professor Steven van de Par, University of Oldenburg, Germany.



Professor Dr. ir. Emanuël Habets, Int. Audio Labs Erlangen, Germany.



Professor Mike Brookes, Imperial College London, England.







Dr. Manuel Segovia-Martinez, Oticon Medical, France.



Dr. Carina Graversen, Eriksholm Research Center, Denmark.



Dr. Asger H. Andersen, Oticon A/S, Denmark.



Dr. Mojtaba Farmani, Oticon A/S, Denmark.



Phd researcher Morten Kolbæk, AAU, Denmark.



Dr. Meng Guo, Oticon A/S, Denmark.



Dr. Søren Riis, Oticon Medical, Denmark.



Dr. Adel Zahedi, Aalborg University, Denmark.



## NEWS

On September 1, 2017, Daniel Michelsanti was employed as a PhD student in CASPR. The title of his PhD project is "Audio-Visual Speech Enhancement for Hearing Assistive Devices ". The project is in cooperation with Oticon.



2018 IEEE 28th International Workshop on Machine Learning for Signal Processing (MLSP2018) will be held in Aalborg, Denmark, September 17-20, 2018, with Zheng-Hua Tan as the general chair. This series of workshops is the major event organized annually by the IEEE Machine Learning for Signal Processing Technical Committee, and is sponsored by the IEEE Signal Processing Society.

Professor Zheng-Hua Tan gave his professorship inaugural lecture on 23 Nov 2017. Title of the lecture: "Deep Learning for Signals and Data: Intelligent Machines are Reshaping Our World".



Morten Kolbæk has received the best student paper award at the IEEE 27<sup>th</sup> International Workshop on Machine Learning for Signal Processing (MLSP), Tokyo, Japan, 25-28 September 2017.

The paper was entitled "Joint Separation and Denoising of Noisy Multi-Talker Speech Using Recurrent Neural Networks and Permutation Invariant Training" by M. Kolbæk, D. Yu, Z.-H. Tan and J. Jensen,



Please visit the CASPR website <u>http://caspr.es.aau.dk</u> for more news.

### **Recent CASPR Related Research Publications**

#### **Journal Papers**

- Spoofing Detection in Automatic Speaker Verification Systems Using DNN Classifiers and Dynamic Acoustic Features. H. Yu, Z.-H. Tan, Z. Ma, R. Martin, and J. Guo, accepted by IEEE Transactions on Neural Networks and Learning Systems, 2017.
- Robust Voice Liveness Detection and Speaker Verification Using Throat Microphones. M. Sahidullah, D.A.L. Thomsen, R.G. Hautamaki, T. Kinnunen, Z.-H. Tan, R. Parts, M. Pitkanen, accepted by IEEE/ACM Transactions on Audio, Speech and Language Processing, 2017.
- iSocioBot A Multimodal Interactive Social Robot. Z.-H. Tan, N.B. Thomsen, X. Duan, E. Vlachos, S.E. Shepstone, M.H. Rasmussen and J.L. Højvang, accepted by International Journal of Social Robotics, 2017.
- Incorporating Pass-Phrase Dependent Background Models for Text-Dependent Speaker Verification. A. Sarkar and Z.-H. Tan, accepted by Computer Speech & Language, 2017.
- 5. Latent Dirichlet Mixture Model. J.-T. Chien, C.-H. Lee and Z.-H. Tan, accepted by Neurocomputing, 2017.
- Visual Detection of Events of Interest from Urban Activity. S. Astaras, A. Pnevmatikakis and Z.-H. Tan, accepted by Wireless Personal Communications, vol. 97, no. 2, November 2017, pp. 1877–1888.
- Multi-talker Speech Separation with Utterance-level Permutation Invariant Training of Deep Recurrent Neural Networks. M. Kolbæk, D. Yu, Z.-H. Tan and J. Jensen, accepted by IEEE Transactions on Audio, Speech and Language Processing, vol. 25, no. 10, October 2017, pp. 1901-1913.

#### **Conference Papers**

- Time-Contrastive Learning Based DNN Bottleneck Features for Text-Dependent Speaker Verification. A.K. Sarkar and Z.-H. Tan, NIPS 2017 Time Series Workshop, CA, USA, Dec. 8, 2017.
- An Upper Bound to Zero-Delay Rate Distortion via Kalman Filtering for Vector Gaussian Sources. P. A. Stavrou, J. Østergaard, C. D. Charalambous, M. Derpich, IEEE Information Theory Workshop (ITW), Kaohsiung, Taiwan, 2017.
- Weighted Score Based Fast Converging CO-training with Application to Audio-Visual Person Identification. X. Duan, N.B. Thomsen, Z.-H. Tan, B. Lindberg and S.H. Jensen, The 29th IEEE International Conference on Tools with Artificial Intelligence (ICTAI2017), Boston, Massachusetts, USA, Nov. 6-8, 2017.
- Joint Separation and Denoising of Noisy Multi-Talker Speech Using Recurrent Neural Networks and Permutation Invariant Training, M. Kolbæk, D. Yu, Z.-H. Tan and J. Jensen, IEEE 27th Int. Workshop on Machine Learning for Signal Processing (MLSP), Tokyo, Japan, Sept. 2017. Best student paper award.
- A Lower Bound to Causal and Zero Delay Rate Distortion for Scalar Gaussian Autoregressive Sources. P. Stavrou and J. Østergaard. Symp. Information Theory and Signal Processing in the Benelux. Delft, The Netherlands, 2017.
- On the Use of Band Importance Weighting in the Short-Time Objective Intelligibility Measure. A. H. Andersen, Z.-H. Tan, J. M. de Haan, and J. Jensen, Proc. Interspeech 2017, pp. 2963 - 2967, 2017.
- Humans do not maximize the probability of correct decision when recognizing DANTALE words in noise. M. Z. Jahromi, J. Østergaard and J. Jensen, Proc. Interspeech 2017, pp. 1163 - 1167, 2017.
- 8. Binaural Beamforming Using Pre-Determined Relative Acoustic Transfer Functions. A. Koutrouvelis, R. C. Hendriks, R. Heusdens, J. Jensen, M. Guo, Proc. 25th European Signal Processing Conference (EUSIPCO 2017), 2017.
- Binaural Speech Enhancement with Spatial Cue Preservation Utilising Simultaneous Masking. A. Koutrouvelis, J. Jensen, M. Guo, R. C. Hendriks, R. Heusdens, Proc. 25th European Signal Processing Conference (EUSIPCO 2017), pp. 628 - 632, 2017.
- 10. Adversarial Network Bottleneck Features for Noise Robust Speaker Verification. H. Yu, Z.-H. Tan, Z. Ma and J. Guo, Proc. Interspeech 2017,
- 11. Conditional Generative Adversarial Networks for Speech Enhancement and Noise-Robust Speaker Verification. D. Michelsanti and Z.-H. Tan, Proc. Interspeech 2017.
- 12. Improving Speaker Verification Performance in Presence of Spoofing Attacks Using Out-of-Domain Spoofed Data. A. Sarkar, Md Sahidullah, Z.-H. Tan and T. Kinnunen, Proc. Interspeech 2017.

CASPR will have a number of fully funded PhD stipends available in 2018. We are looking for highly motivated, independent, and outstanding students that desire to do a successful 3-year PhD programme at Aalborg University. The ideal candidates must have strong expertise in one or more of the following disciplines: statistical signal processing, auditory perception, machine learning, information theory, or estimation theory. Good English verbal and written skills are a must. Excellent undergraduate and master degree grades are desired. PhD positions in Denmark are fully funded, i.e. no tuition fees, and come with a salary. The salary is subject to a pay grade system based on prior working experience since completing your undergraduate degree. The yearly gross salary is in the range 41.500 – 50.100 Euros.

You may obtain further information about the PhD stipends from Professor (MSO) Jan Østergaard (jo@es.aau.dk), Professor Zheng-Hua Tan (zt@es.aau.dk), or Professor Jesper Jensen (jje@es.aau.dk), CASPR, Aalborg University, concerning the scientific aspects of the stipends.

> Aalborg University (http://www.en.aau.dk/) is one of the leading Danish universities with campuses in Aalborg, Esbjerg and Copenhagen. The student population of AAU comprises of around 21.000 regular (both undergraduate and postgraduate) students and 947 PhD students. AAU is famous for its innovative problem and project based learning approach (PBL) where students work on team-based projects solving 'real-life' problems in collaboration with organisations or companies. Aalborg University is acknowledged for collaboration with industry and according to Shanghai/ARWU World Rank, Aalborg University is no.7 in the world within the research field of Electronic and Electrical Engineering. Aalborg University is ranked the best university in Europa and the eighth best university worldwide for engineering according to the Best Global Universities list published by U.S. News and World Report, 2017.