PASSIVE ONLINE GEOMETRY CALIBRATION OF ACOUSTIC SENSOR NETWORKS

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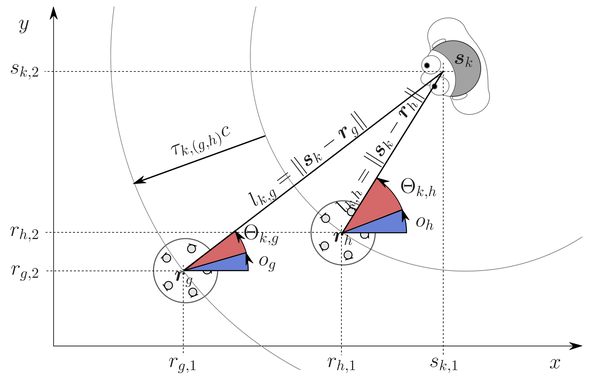
Abstract

As we are surrounded by an increased number of mobile devices equipped with wireless links and multiple microphones, using them collaboratively for acoustic processing is a promising platform. These devices may constitute an acoustic sensor network (ASN). Many spatial processing algorithms require a precise knowledge of the nodes' locations and orientations. An automated real-time method is proposed to acquire this.

Problem Statement

Goal Calibrate relative geometry of several multi-microphone nodes from ambient speech by distributed online computation.



- G nodes at position $\boldsymbol{r}_g \in \mathbb{R}^d$ with orientation o_g
- Relative geometry [1], fix $\boldsymbol{r}_1 := [0,0]^T, o_1 := 0,$
- find $\boldsymbol{\gamma} = [r_{21}, r_{22} \dots r_{G2}, o_2 \dots o_G]^T$ using K speech events with directions of arrival (DoAs) $\Theta_{k,g}$ and time differences of arrival (TDoAs) $\tau_{k,(g,h)}$

1: Target Function

DoA-TDoA target function [2] for node pair measurement of speech event $\boldsymbol{m}_{k,(g,h)} = \{\Theta_{k,g}, \Theta_{k,h}, \tau_{k,(g,h)}\}$

- Triangulate source position $\hat{\boldsymbol{s}}_k$ from DoAs and geometry.
- The TDoA has to match $\rightarrow$ error function $\epsilon_{g,h}(\boldsymbol{m}_k, \boldsymbol{\gamma})$
- Penalize non-intersection with constant $\epsilon_{\max}$

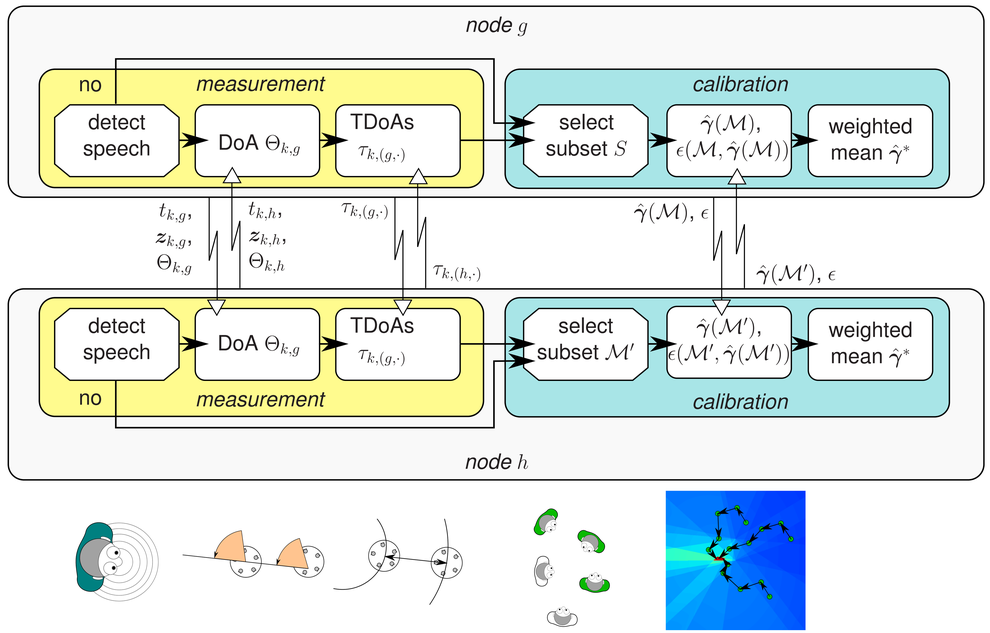
Combined over nodes and subset of all events

- Underdetermined for a single event $\rightarrow$ need min. number
- Nodes select random subsets $\mathcal{M} = \{\boldsymbol{m}_{i,(\cdot,\cdot)}, \boldsymbol{m}_{j,(\cdot,\cdot)}, \dots\}$ for distributed computation of $\hat{\boldsymbol{\gamma}}(\mathcal{M}) = \operatorname{argmin}_{\boldsymbol{\gamma}} \epsilon(\mathcal{M}, \boldsymbol{\gamma})$
- Combine these by weighted mean for overall estimate $\hat{\boldsymbol{\gamma}}^*$

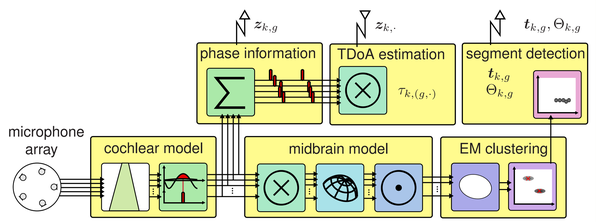
Further Materials

- paper & appendix `http://patrec.cs.tu-dortmund.de/resources`
- code `https://github.com/Plinge/audiogeocal`
- demo video `https://vimeo.com/177715229`

Method Overview



2: Neuro-Inspired SpeechLocalization

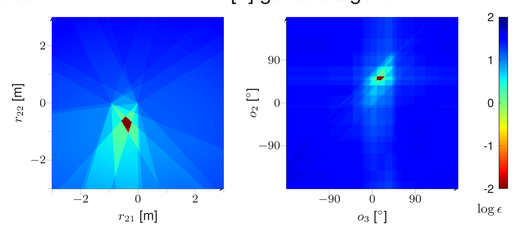


- neuro-inspired model for speaker localization [3]
- detect speech segment k with time span $\boldsymbol{t}_{k,g}$ & DoA $\Theta_{k,g}$
- also transmit sparse spike representation $\boldsymbol{z}_{k,g}$
- TDoAs are estimated by using $\boldsymbol{z}_{k,\cdot}$ from other nodes

3: Genetic Algorithm

Target Function $\epsilon(\mathcal{M}, \boldsymbol{\gamma})$ to minimize

- $\boldsymbol{\gamma}$ high-dimensional $((G-1) \times (d+1))$
- non-intersections cause plateaus
- highly non-continuous and non-differentiable
- use differential evolution [4] genetic algorithm



Cuts through the target function $\epsilon(\mathcal{M}, \boldsymbol{\gamma})$ for an example with $G = 3$

References

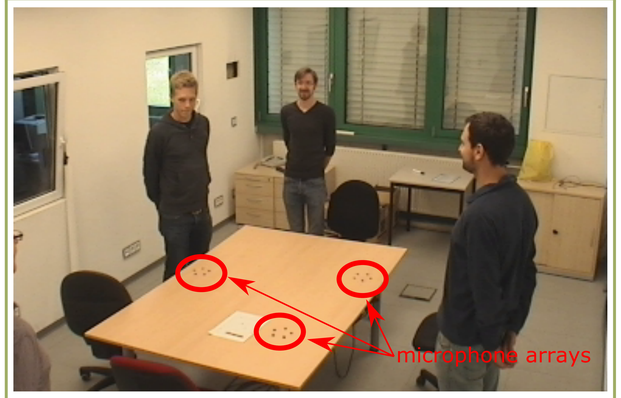
[1] A. Plinge, F. Jacob, R. Haeb-Umbach, and G. A. Fink. Acoustic microphone geometry calibration: An overview and experimental evaluation of state-of-the-art algorithms. *IEEE Signal Process. Mag.*, 33(4), July 2016

[2] A. Plinge and G. A. Fink. Geometry calibration of multiple microphone arrays in highly reverberant environments. In *Int. Workshop on Acoustic Signal Enhancement*, Antibes – Juan les Pins, France, Sept. 2014

[3] A. Plinge and G. A. Fink. Online multi-speaker tracking using multiple microphone arrays informed by auditory scene analysis. In *European Signal Process. Conf.*, Marrakesh, Morocco, Sept. 2013

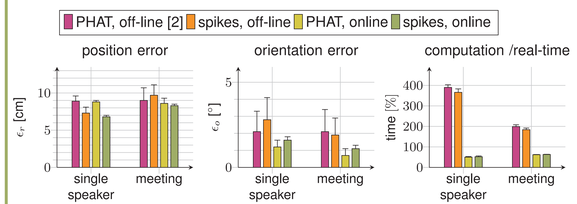
[4] R. Storn and K. Price. Differential evolution – a simple and efficient heuristic for global optimization over continuous spaces. *Journal on Global Optimization*, 11:341 – 359, 1997

Evaluation

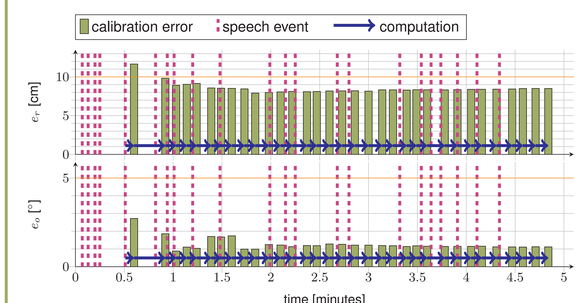


- Smart conference room ($T_{60} = 0.67\,\mathrm{s}$)
- Three 5-mic uniform circular arrays in table (48 kHz)
- Sequence #1 single speaker at $K = 19$ sitting / standing positions
- Sequence #2 four persons in a meeting ($K = 22$, picture above)
- 100 Monte-Carlo runs
- Subset size $|\mathcal{M}| = 5$
- Population size 10 for genetic algorithm

Method Comparison



Example Run (Meeting)



Conclusion

The proposed approach is able to calibrate an acoustic sensor networks' geometry online during a meeting in a reverberant conference room.