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Microphone Array Position Self-Calibration from Reverberant Speech Input

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Introduction

- The geometry of an acoustic sensor network is required for many signal processing applications
- Existing approaches often use artificial calibration signals or special hardware to achieve high positioning accuracy
- Here: Relative inter-array calibration based on speech input

Scenario

- 4 microphone arrays (red circles)
- Retrieve inter-array geometry:
  - Sensor positions
  - Sensor orientations
- Calibration input: reverberant audio signal of moving speaker

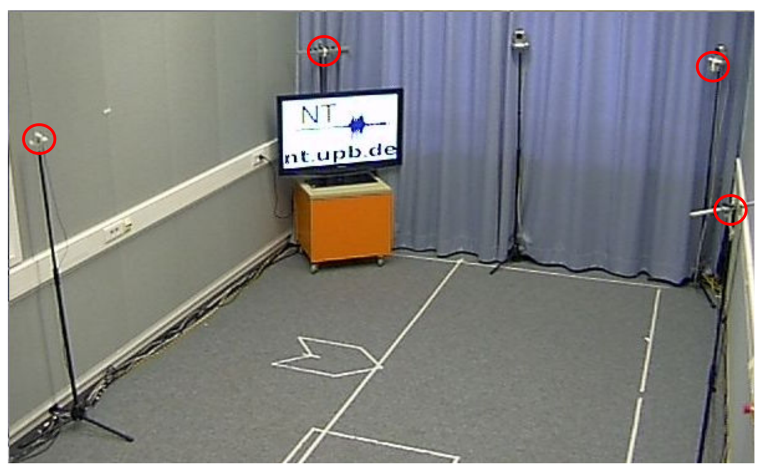

Figure 1: Scenario

Structure of online calibration system

1. Estimate direction of arrival (DoA)
2. Determine geometry parameters
3. Display calibration result

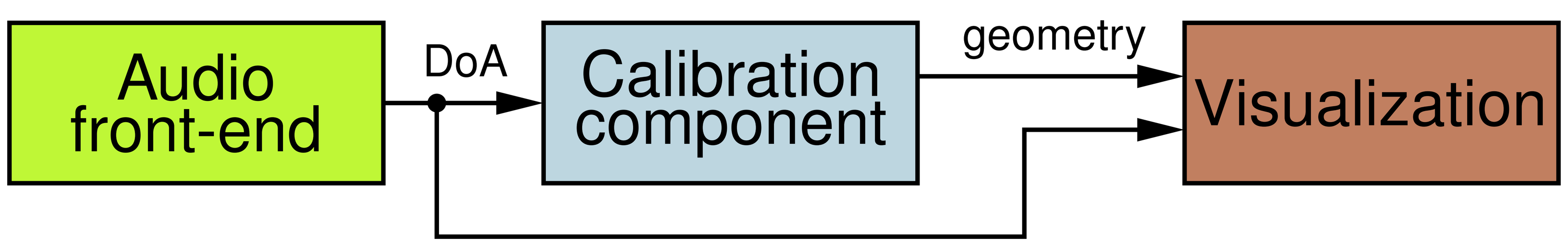

Figure 2: Block diagram of online demonstrator system

Audio front-end

- Each array consists of 2 microphones (Distance 5 cm)
- Multi-channel sound card to digitize audio signals
- Filter-and-sum beamformer (FSB) for blind beamforming
- Correlation of filter coefficients delivers time difference of arrival (TDoA) estimates

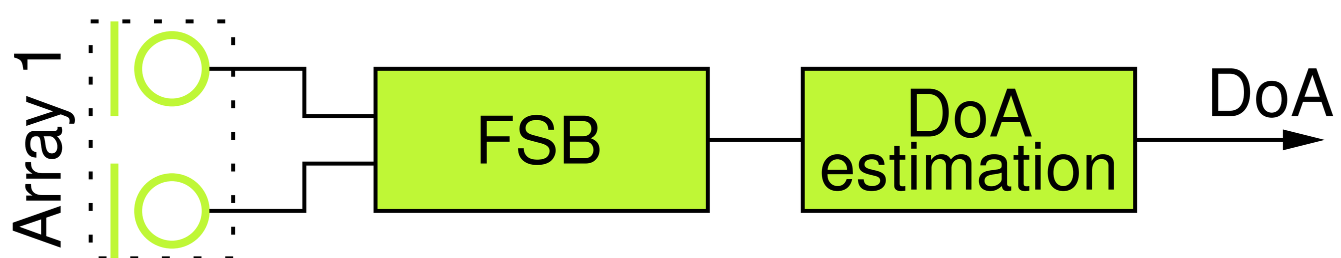

Figure 3: Audio front-end of a microphone array

- DoA estimates can be obtained form TDoA estimates using far-field assumption and array geometry

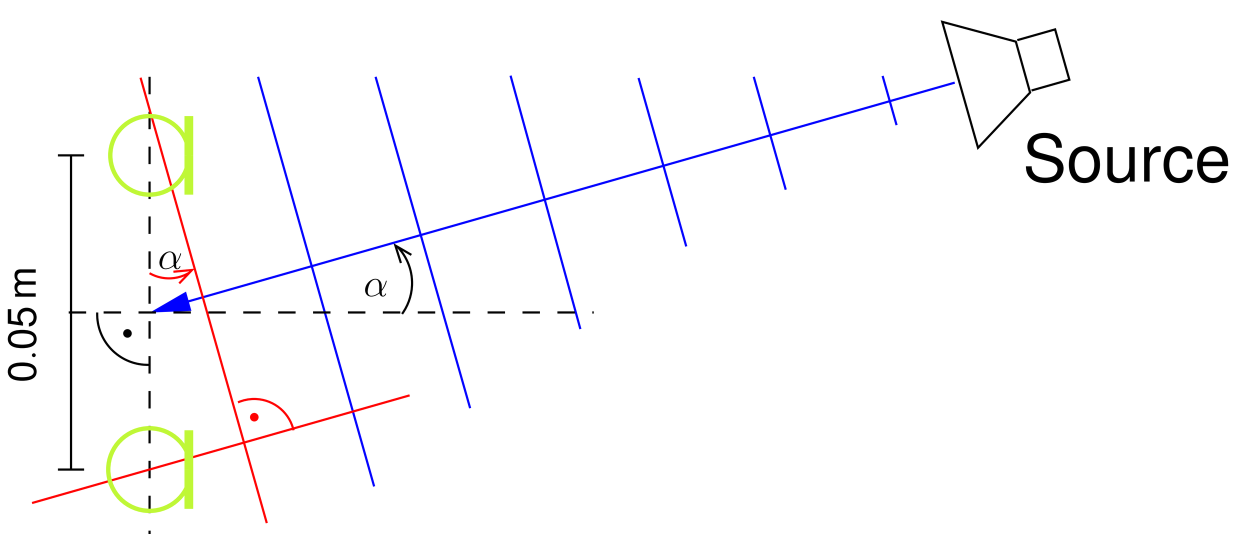

Figure 4: DoA estimation

Calibration component

- Two steps:
  - Iterative cost function optimization for parameter estimation
  - Rejection of measurement outliers caused by reverberation
- Hardware & Software:
  - Intel® Core™ i7 960 @ 3.20 GHz with 6 GB RAM
  - Ubuntu 10.04 LTS
- Requirements for online calibration:
  - New DoA estimate every 125 ms
  - Periodically solve system of approximately 200 equations

⇒ Partitioned parallel calibration to keep complexity manageable

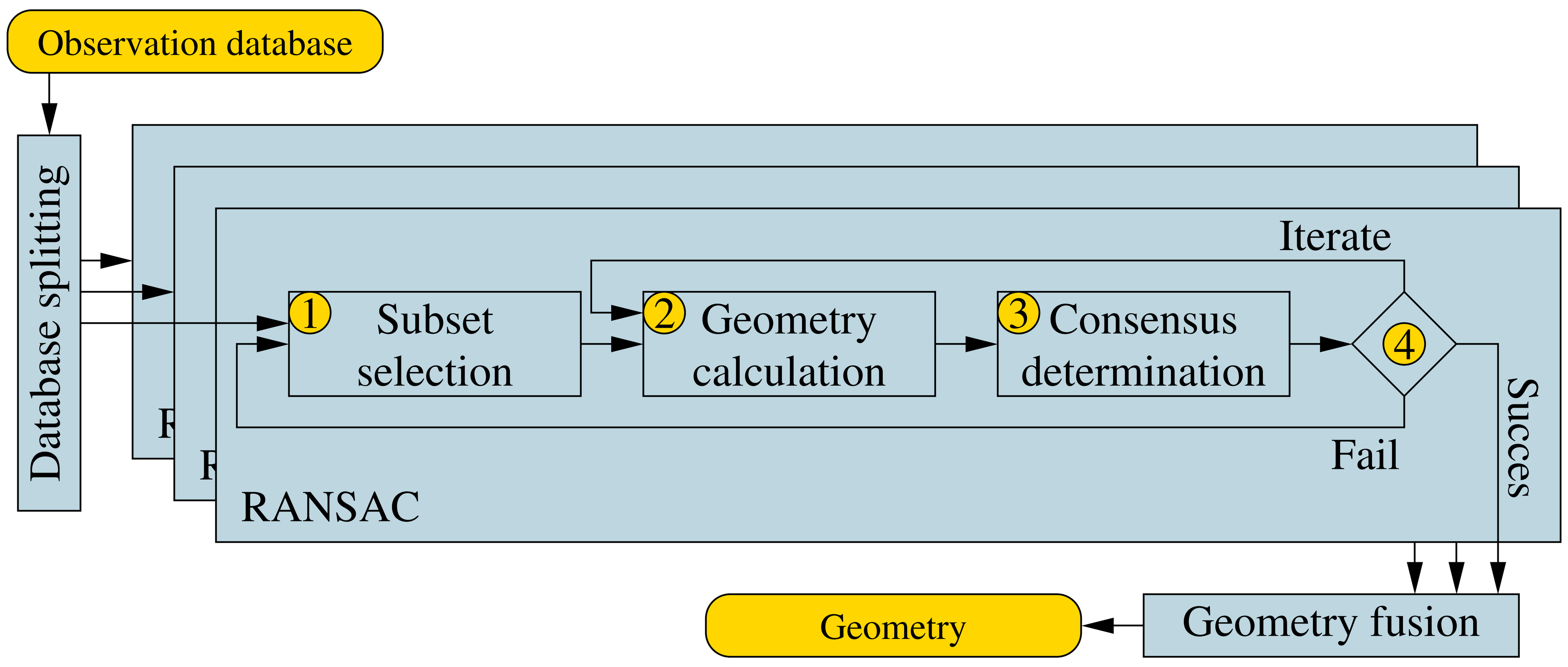

Figure 5: Block diagram of calibration algorithm

1. Select random subset of DoA measurements
2. Calculate geometry parameters using "Newton's method"
3. Observations that fit to current parameters form the consensus set

Iterate: Repeat parameter estimation with consensus set
Success: Geometry matches sufficient observations
Fail: Restart with new DoA subset

Calibration result & visualization

- Result of calibration procedure is arbitrarily orientated relative geometry
- Matching between calibration result and reference geometry required for visualization
- Mean positioning error: 0.25 m in real environments with $T_{60} = 160$ ms

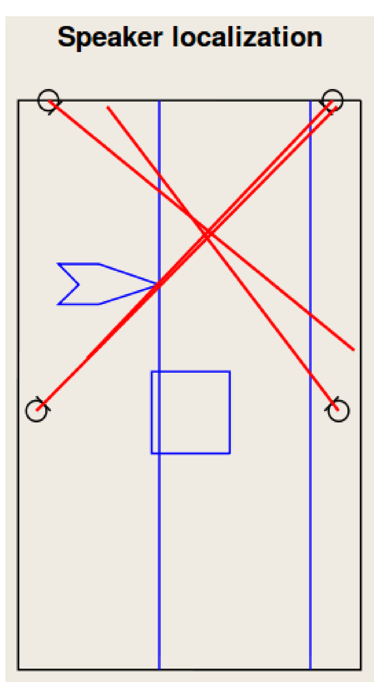

Figure 6: Localization result of DoA measurements (red lines) based on reference geometry (black marks)

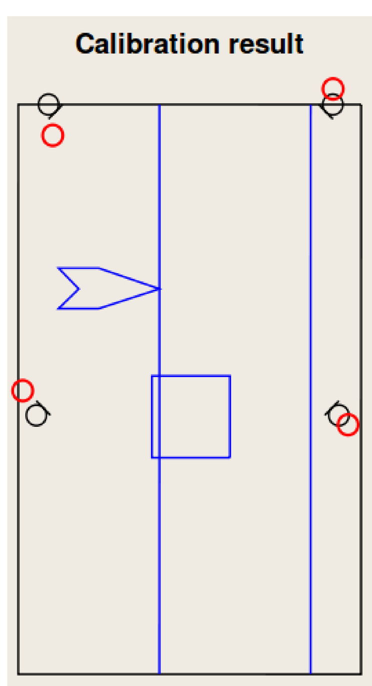

Figure 7: Comparison of calibrated microphone positions (red circles) and reference geometry (black marks)

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