# TUT 2005 SLOC System

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# Outline

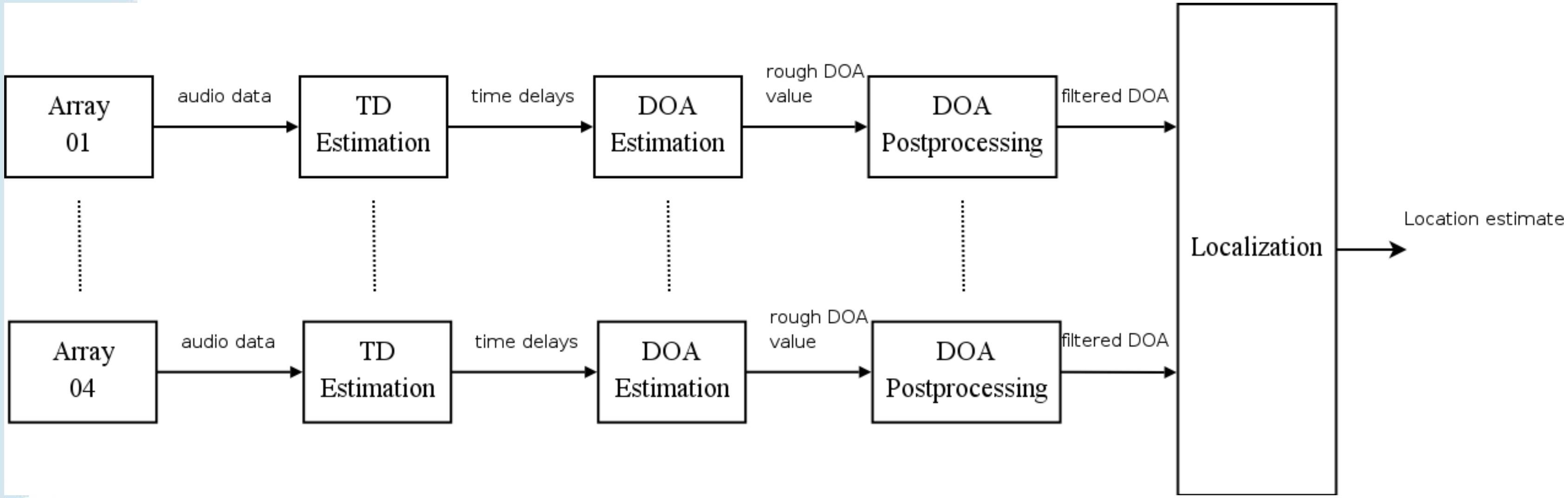
- Background
- System Overview
- Time Delay Estimation
- Direction of Arrival Estimation
- Location Estimation
- Results
- Conclusions

## Background

- A performance test of an existing system
- “Could the system be considered for speech applications”?
- “Simple” method, few assumptions
- Relies on time delay based propagation vector estimation
- Not aggressively tuned for speech or this eval

# System Overview

- Independent time delay based DOA estimation from each array
- Combine results into a single location estimate at the last stage
- Four arrays (msla), four sensors in each



# Time Delay Estimation

- Pairwise GCC-PHAT[1]: find $\tau$ that maximizes

$$R_{(1,2)}(\tau) = \mathcal{F}^{-1}\left\{\frac{X_1(\omega)^* X_2(\omega)}{|X_1(\omega)^* X_2(\omega)|}\right\} \tag{1}$$

- Extract time delay from cross-spectral phase
  $\longleftarrow$Amplitude is whitened out
- 44.1 kHz sample rate, 24 bits per sample
- 0.74 sec window, 50 % overlap $\rightarrow$2.68 frames / sec
- Sample rate resolution, no interpolation
- Six pairs from each array (four mics in one array)

[1] Knapp, Carter, "The Generalized Correlation Method for Estimation of Time Delay," IEEE Trans. Signal Processing, vol. 24, pp. 320–327, August 1976

# Direction of arrival estimation

- Two best (out of six) time delays selected with confidence scoring[2]
  →Reduces RMS errors of arrays B and D by 1/3

- 2D propagation vector estimation[3] at each array

$$\hat{\mathbf{k}} = \left(\mathbf{X}^{\mathsf{T}}\mathbf{X}\right)^{-1}\mathbf{X}^{\mathsf{T}}\hat{\boldsymbol{\tau}} \quad (2)$$

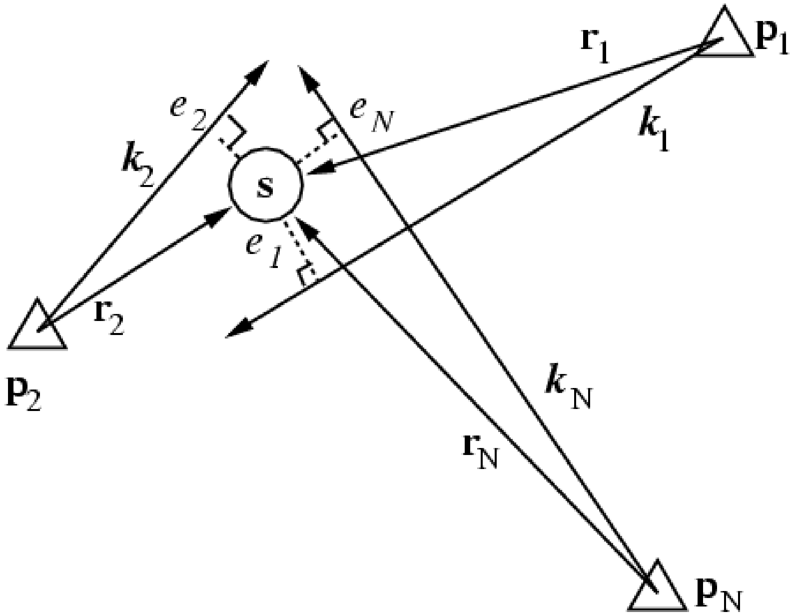
- Postprocessing = 9-pt median filtering

[2] Pirinen, "Normalized Confidence Factors for Robust Direction of Arrival Estimation," in Proc. IEEE-ISCAS 2005, pp. 1429–1432.
http://www.cs.tut.fi/sgn/arg/tuomop/iscas2005.pdf

[3] Yli-Hietanen, Kalliojärvi, Astola, "Low-Complexity Angle of Arrival Estimation of Wideband Signals Using Small Arrays," in Proc. IEEE-SSAP'96, pp. 109–112.
http://www.cs.tut.fi/sgn/arg/ypsilon/SSAP96PAPERFM4SENT.PDF

# Location Estimation

- Weighted least squares estimate of source position[4]
- Estimate the "optimal intersection" of estimated directions from each array
- Location estimate = The point with minimum distance to DOA lines




[4] Hawkes and Nehorai, "Wideband Source Localization Using a Distributed Acoustic Vector-Sensor Array,Ž" IEEE Trans. Signal Processing, vol. 51, pp. 1479–1491, June 2003

# Results

- Eval set:

| | Lecturer/Overall | |
|---|---|---|
| Pcor | 0.57 | |
| Bias fine (x,y,z)[mm] | (94,38,-115) | |
| Bias fine+gross (x,y,z)[mm] | (360,10,-217) | |
| RMSE fine [mm] | 307 | |
| RMSE fine+gross [mm] | 851 | |
| Deletion rate | 0.00 | (SAD was not used) |
| False Alarm rate | 0.98 | (SAD was not used) |

- Runtime 4.3×RT (2.8 GHz Pentium 4, 2.1 Gb RAM)
  99.7 % for TDE

# Conclusions

- Considering the relative simplicity of the system, results are satisfactory
- Eval set favored the system: Pcor $\approx 0.35$ in training data
- Too much smoothing (long window, median filter + averaging in scoring )
- Tracking and activity detection needed
- Definition of "spatial" activity?
- Could information from arrays be combined earlier?
- Adaptive weighting of arrays?

# Summary

- A time delay based localization method
- DOA estimation at each array
- Selection of time delays
- Localization with “optimum intersection”
- Array weighting
- No activity detection
- System is worth further consideration