Title
Acoustic Sensor Networks for Woodpecker Localization

Authors
H. Wang
C. E. Chen
A. Ali
et al.

Publication Date
2005

CENS Center for Embedded Networked Sensing

Acoustic Sensor Networks for Woodpecker Localization

H. Wang, C. E. Chen, A. Ali, S. Asgari, R.E. Hudson, K. Yao, D. Estrin, and C. Taylor
UCLA CENS

Introduction: design and implementation of acoustic arrays

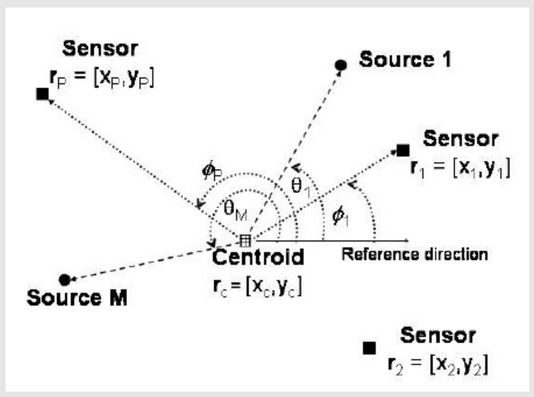
AML Algorithm for Wideband DOA estimation

- The AML algorithm performs signal separation by utilizing the physical separation of the sources, and for each source signal, the SINR is maximized in the ML sense

Sensor Spacing for Robust Beamforming

- The shape of the maximum-likelihood criterion J(?) directly affects the precision/robustness of our DOA estimation.
- Small Array is more preferable in multipath environment

AML algorithm basics:



M wideband sources, P sensors

Derivation of AML Algorithm

Data received by the pth sensor at time n:

$$x_p(n) = \sum_{m=1}^{M} S^{(m)}\left(n - t_{cp}^{(m)}\right) + w_p(n)$$

After N point DFT

$$\mathbf{X}(w_k) = \mathbf{D}(w_k)\mathbf{S}(w_k) + \mathbf{?}(w_k)$$

where $\mathbf{R}(w_k) = \mathbf{X}(w_k)\mathbf{X}^H(w_k)$

$$\mathbf{P}(w_k, \mathbf{T}) = \mathbf{D}(w_k)\mathbf{D}^+(w_k)$$

$$\mathbf{D}^+(w_k) = \left(\mathbf{D}^H(w_k)\mathbf{D}(w_k)\right)^{-1}\mathbf{D}^H(w_k)$$

By technique of separating variables, we can estimate DOA as:

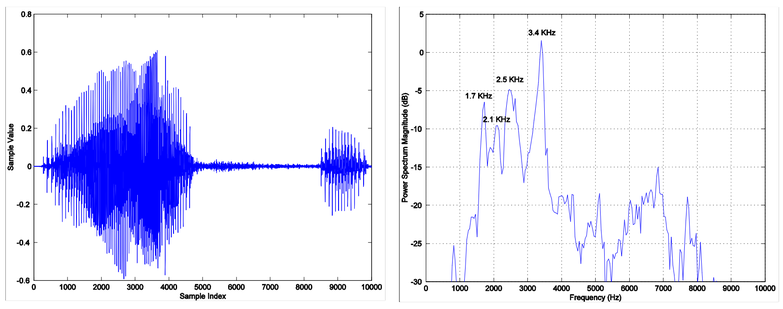
$$\hat{\mathbf{T}} = \arg\max_{\mathbf{T}} J(\mathbf{T}) = \arg\max_{\mathbf{T}} \sum_{k=1}^{L} tr\left(\mathbf{P}\left(w_{l(k)}, \mathbf{T}\right)\mathbf{R}\left(w_{l(k)}\right)\right)$$

In multiple sources case, AML requires multi-dimensional search.

Various numerical solutions (AP, GN, CG) were have been proposed.

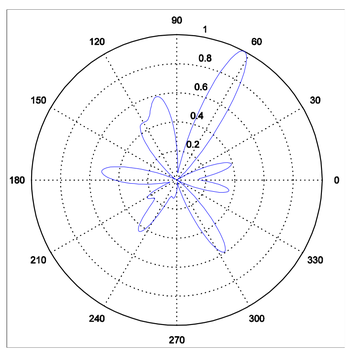
Simulations and Experimental Results:

Waveforms of woodpecker vocalization

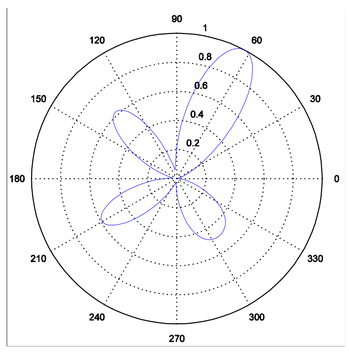


Typical waveform in time and frequency domain of woodpecker vocalization.

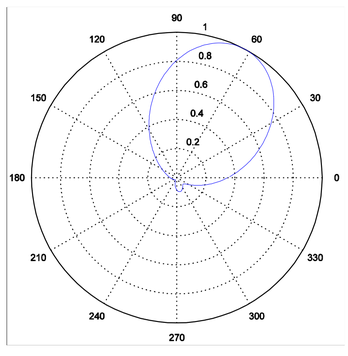
Beam patterns of different array sizes



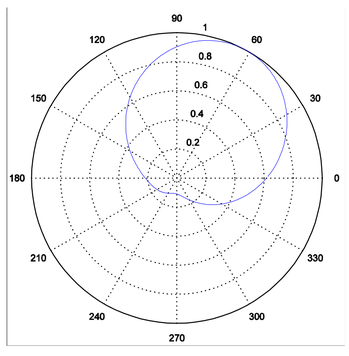
d=20cm,simulation



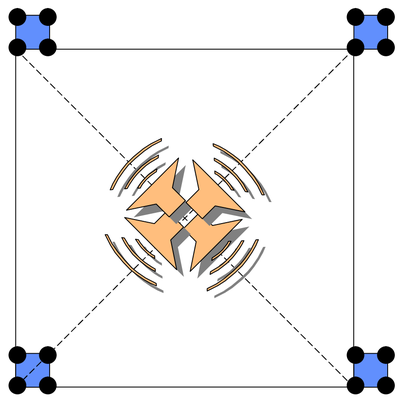
d=10cm,simulation



d=4cm, simulation

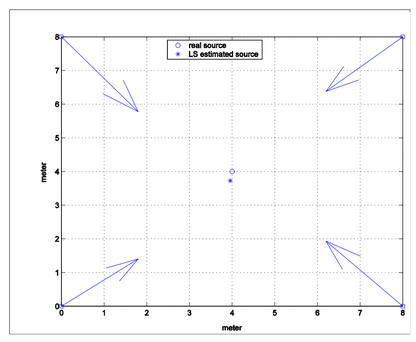


d=4cm, experiment

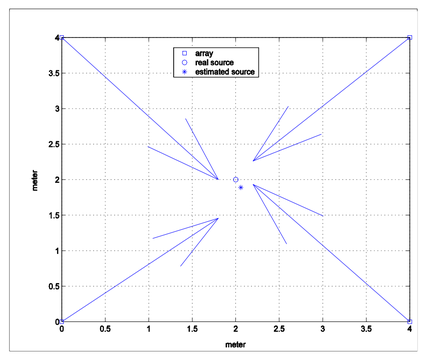


Settings and experimental results:

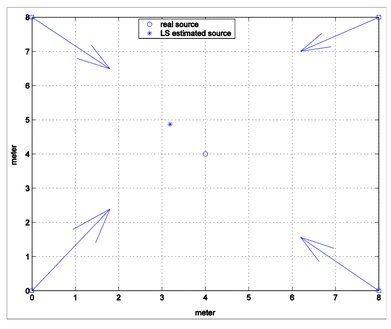
- DOA for each subarray is first estimated by AML algorithm
- Source location is then estimated by applying least-square fit to 4 bearing crossings
- To investigate the localization performance, experiments are performed under different environments.



Parking lot in Buckley School
- Open Area
- relatively quiet environment



UCLA science courtyard
- Relatively open area
- Strong ambient noise
- Strong wind noise



Woody hill of Buckley School
- Dense tree crowns
- Strong multipath
- Rough terrain

UCLA – UCR – Caltech – USC – CSU – JPL – UC Merced