2D and 3D Acoustic Source Localization Using the AML Algorithm and ENSBox Nodes

https://escholarship.org/uc/item/92q6c9xp

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Introduction: Localization by fusing AML bearing estimates from multiple nodes

Problem Description: Field deployment can be harsh and the algorithm has to be robust

Proposed Solution: Deploy ENSBox as sub-array and estimate from weighted log-likelihood

Deployment Overview
- ENSBox nodes manage themselves and able to perform self-node-localization
- Each node records and detects the event, and then run the AML algorithm
- Result is sent to a fusion center to be combined for localization

Approximate Maximum Likelihood (AML)
- Signal Model
  - Time domain: \( x(t) = s(t) + n(t) \)
  - Freq domain: \( X(w) = \hat{X}(w)e^{-j2\pi w t + \eta(t)} \)
- Optimal under Gaussian noise (approaches CRB)
  - \( \text{DOA} = \arg \max (\sum P(w_i, X(w_i)) \text{SNR}) \)
  - where, \( P = DD' \)

Algorithm Issue
- Performance depends on source signal and array size, position and orientation
  - Closely spaced dominant frequencies is close to narrowband
  - Small array size removes ambiguity but has wide main-lobe
- Bearing fuse problem
  - Orientation error and non-uniform signal gain render the maximum likelihood (ML) weighting ineffective
- Reverberation
  - Reflection off the trees or buildings introduce bias

ENSBox Architecture
- A self-contained processor and array with an internal battery, weather-resistant packaging and tripod mount ready
- A web-based management and diagnostic tool to identify problems with individual nodes
- A multi-hop wireless network and a sophisticated array self-calibration system that can establish precise positions and orientations (within 10 cm and 1.5 degree in a 50 x 80 m field)
- A synchronized sampling API that greatly simplifies the development of collaborative sensing application software

Fuse Strategy
- Log-likelihood weight selection
  - Weight maximum based on ML (no weighting)
  - Lower bound minimum based on SNR
- Combining Strategy
  - Create a search map (2D or 3D) and divide into grids
  - Compute functional evaluation at each grid point by summing each node’s log-likelihood value that points to the current evaluated position with the appropriate weight

Detection Overview
- Version 1: tetrahedral 4 element array with 6 cm side length from top view
- Version 2: tetrahedral 4 element array with 12 cm side length from top view

Localization in Action

Position & Bearing Estimation Results
- 2D position estimates: \((x,y)\) in meters
- 3D bearing estimates: (azimuth, elevation) in degrees

Table: Position & Bearing Estimation Results

<table>
<thead>
<tr>
<th>Case</th>
<th>Mean (x)</th>
<th>Std. Dev. (y)</th>
<th>RMSE Dist.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICH Marmot</td>
<td>(39.01, 15.59)</td>
<td>(0.03, 0.09)</td>
<td>0.78</td>
</tr>
<tr>
<td>ICH Neise</td>
<td>(38.27, 13.31)</td>
<td>(0.02, 0.04)</td>
<td>0.35</td>
</tr>
<tr>
<td>ICH Marmot</td>
<td>(24.92, 12.30)</td>
<td>(0.47, 0.22)</td>
<td>2.07</td>
</tr>
<tr>
<td>ICH Neise</td>
<td>(27.10, 13.68)</td>
<td>(0.18, 0.08)</td>
<td>0.61</td>
</tr>
</tbody>
</table>

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