Acoustic Source and Wireless Sensor Node Localizations

A. Ali, S. Asgari, C.E. Chen, B.H. Cheng, R.E. Hudson, F. Lorenzelli,
E. Tacinroglu, L. Vandenberghe, and K. Yao

Introduction: Finding the locations of an emitting acoustic source as well as those of wireless sensor nodes are needed in many sensor networking applications

Acoustic Source Localization Algorithms

- **Maximum-Likelihood (ML) DOA Estimation**
  - ML-based DOA estimation is near optimum for high SNR
  - Modified ML critieron narrowband array to perform DOA for wideband acoustic sources; cross-bearing of est. DOAs yields source localization
  - Source signal is transformed using FFT onto frequency domain and dominant subbands are used under the Aproximate ML (AML) criterion
- **AML for Reverberant and Impulsive Source DOA Est. Exp.**
  - Conducted controlled reverberance experiment using "virtual array" method
  - Conducted field measurement of impulsive source for DOA estimation

Distributed Sensor Node Localization Algorithms

- **Localization Based on Neighborhood Ranging Information**
  - Ranging measurement d_{ij} between node i and node j if the distance is less than the radio range R.
  - Anchor nodes a_k with known location.
- **Distributed Algorithms**
  - Each node updates its own location using Gauss-Newton (GN) method
  - Use only local information and transmit to the neighboring nodes
  - Reduce computation complexity from $O(n^3)$ to $O(n)$
- **Reduced communication cost**

Problem Description: Some details on source and sensor node localization algorithms

AML-based DOA Estimation

- Controlled reverberant scenario having only two perpendicular walls, one subarray with known location, to estimate one source with unknown location
- Using "virtual array" model and AML estimation, only one consistent ray from each virtual subarray passes through the location of the source
- Upon hammering a solid plate on the ground, short impulsive acoustic and sesmic waves were generated
- Localization of plate obtained using AML DOAs est, of whitened data

Gauss-Newton Distributed Estimation

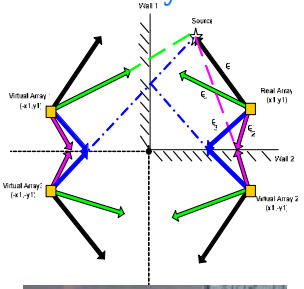
$$F(x)=\sum_{i,j}\left|\|x_i-x_j\|^2-d_{ij}^2\right|^2+\sum_{i,k}\left|\|x_i-a_k\|^2-d_{ik}^2\right|^2 \quad \text{Global Cost Function}$$

$$F_i^{(t)}(x_i)=\sum_{j\to i}\left|\|x_i-x_j^{(t)}\|^2-d_{ij}^2\right|^2+\sum_{k\to i}\left|\|x_i-a_k\|^2-d_{ik}^2\right|^2 \quad \text{Local Cost Function at the } i\text{-}th \text{ node}$$

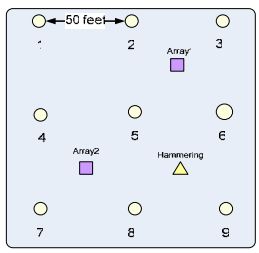
- Given $x_j^{(t)}$ minimizing the local cost function over x_i using GN method
- Transmit the updated estimation $x_i^{(t+1)}$ to the neighboring nodes
- Non-increasing value of the global cost function

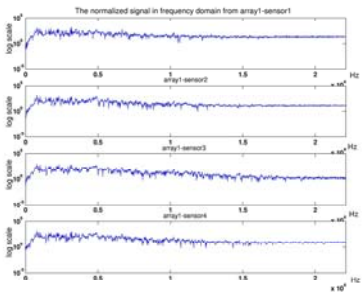
Proposed Solution: AML DOA and Gauss-Newton distributed algorithms for localizations

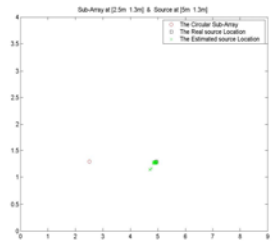
Virtual Array Model

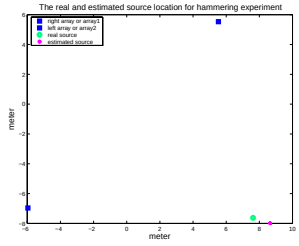


Hammering Impulsive Source









Sequential algorithm

Given starting point

for *i=1:1:n*

- Minimizing local cost function.
- Find step length.
- Update the estimation
- Transmit to all the neighboring sensors.

end

t=t+1

Parallel algorithm

Given starting point

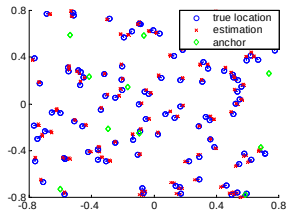
Minimizing local cost function

for *i=1:1:n*

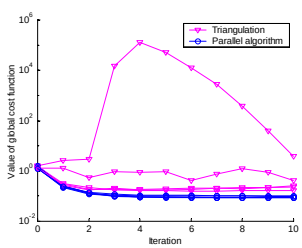
- Find step length
- Update the estimation.
- Transmit to all the neighboring sensors.

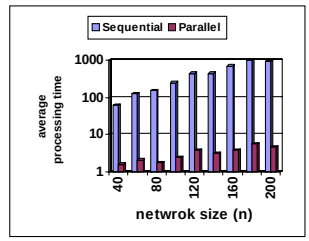
end

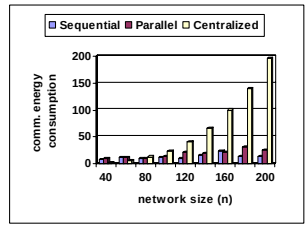
t=t+1



Estimation Results







Local. of reverb. acoustic source and hammering plate

Performance of Gauss-Newton dist. algorithm