Tonal and Harmonic Source Localization using Acoustic Vector Sensors

Universidade de Vigo

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Microflown AVISA — 3D Acoustic Situational Awareness

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Motivation

With the number of non-controlled flying and sailing vehicles going up, also the need to monitor their trajectories in the space increases. Moving sound source localization and tracking for outdoors measurements under non-controlled conditions usually leads to non-linear and non-stationary problem:

- Non-Stationary Background Noise.
- Non-Stationary Acoustic Sources .
- The number of active sources is unknown and time-varying.

Most of the acoustic sources of interest have strong tonal, harmonic or quasi-harmonic components within their acoustic signature, as planes, boats, helicopters, UAVs, drones, etc.

Potential Targets

Objectives

The main objective of the thesis is to develop a framework for detecting, localizing and tracking tonal or harmonic sources using a wireless distributed network of Acoustic Vector Sensors (AVS). The main task is to design algorithms for:

- Sensors with DSP and communication capabilities: Detection, source separation and source tracking algorithms for a single AVS.

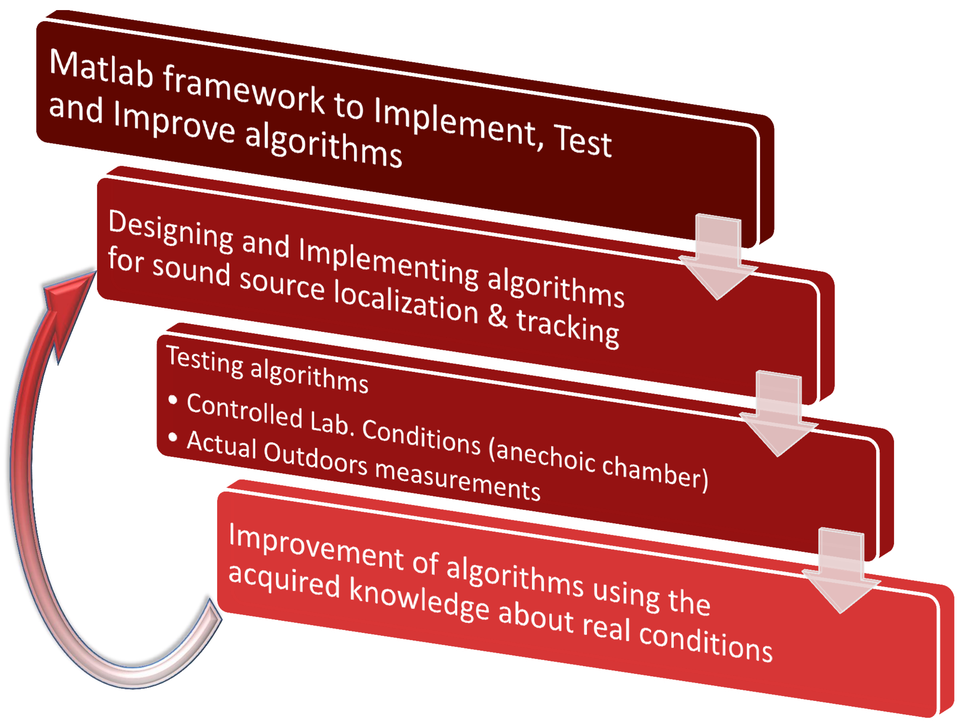
- Central processor: Source localization and tracking algorithms to combine the information collected by the AVS within the network.

Key objectives for this year

- Data gathering.
- Doppler-bearing fusion for tracking moving tonal/harmonic sound sources using a network of AVS.
- Approaches for tracking an unknown and time-varying number of targets.
- Design and improvement of algorithms to account and compensate for effects of real conditions.

Methodology

Field and laboratory research is mixed to achieve a quantitative comparison of the algorithms.



Different scenarios with different levels of complexity are considered.

Research Plan

This year	2016		2017								
	Nov	Dec	Jan	Feb	March		Jun	Aug	Sep	Oct	
Tasks	1	2	3	4	5	6	7	8 (*)	9	10	11
1.Multisensor Tracking DBT											
2. Non-stationary BASS											
3. Implementation											
4. Tests											
5. Publications (Journals)											

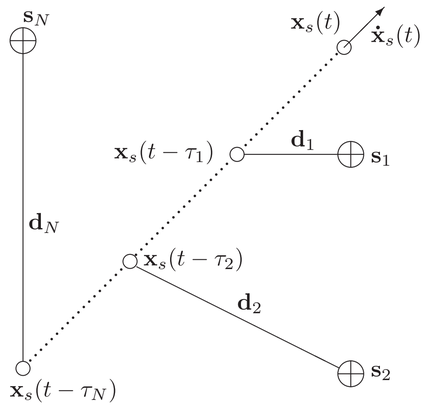
Results and Discussion

- Relativistic measurement model for far field DOA (N sensors located at $\mathbf{s_i}$).

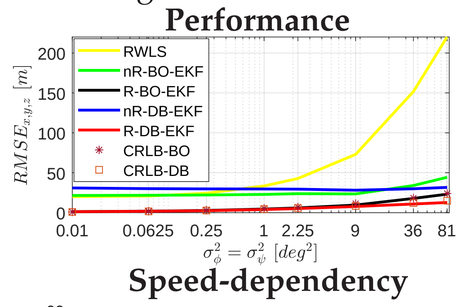
$$v_i(\mathbf{s_i},t) = p_i(\mathbf{s_i},t)\tilde{\mathbf{n}}/\rho c_0 \;\Rightarrow\; \mathbf{y_i}(t) = \begin{bmatrix} y_{p,i}(t) \\ \mathbf{y}_{v,i}(t) \end{bmatrix} = \begin{bmatrix} 1 \\ \mathbf{u_i}(t)/\rho c_0 \end{bmatrix} p_i(t) + \mathbf{e_i}(t)$$

Sensors observe the source at different positions in the past at $\mathbf{x_s}(t-\tau_i)$.

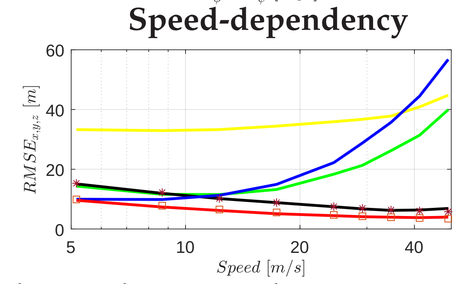
- Constant Velocity (CV) model ⇒ Doppler-Bearing fusion.



Performance

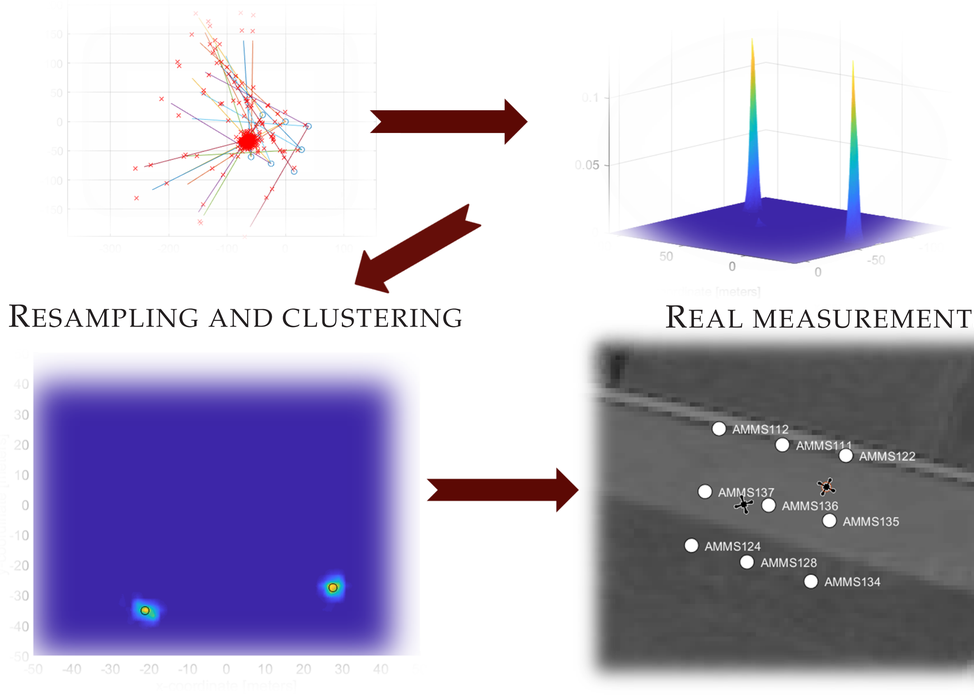


Speed-dependency



- Random Finite Set + Particle filter to track an unknown and time-varying number of sources, m_k.

$$p(X_k|X_{k-1}) = p(B_k|X_{k-1})p(S_k|X_{k-1}) \qquad \omega_k^{(l)} = \omega_{k-1}^{(l)} p(Z_{k,n}|X_k^{(l)})$$



Outcomes (to date)

- Euronoise 2015 Conference Paper: David P. Cabo *et al.* *"Real Life Harmonic Source Localization Using a Network of Acoustic Vector Sensors"*(in Scopus)
- European Rotorcraf Forum 2015 Conference Paper: David P. Cabo *et al.* *"A wireless network of acoustic multimission sensors to detect, locate and track simultaneously various helicopters"*(in Scopus)
- Applied Acoustics Journal Paper: David P. Cabo *et al.* *"Relativistic Measurement Model for Moving Sound Source Tracking using a distributed Network of Acoustic Vector Sensors"* (in peer review)
- IEEE Trans. Sig. Pro.: David P. Cabo *et al.* *"Doppler-Bearing Fusion for Moving Sound Source Tracking using an Acoustic Vector Sensor Array"* (to be submitted)
- IEEE Trans. Sig. Pro.: David P. Cabo *et al.* *"Doppler-Bearing Fusion for Multiple Sound Source Tracking using an Acoustic Vector Sensor Array"* (in progress)

References

[1] Yaakov B. Shalom *et al.*, "State estimation for Non-Linear Dynamic Systems" in *Estimation with Applications to Tracking and Navigation: Theory Algorithms and Software*, John Wiley & Sons, Inc., 2001.

[2] M. Hawkes *et al.*, Wideband Source Localization Using a Distributed Acoustic Vector-Sensor Ar- ray. IEEE Transactions on signal processing , Vol. 51, NO. 6, pp. 1479-1491, June 2003

[3] X. Zhong *et al.*, "Particle filtering approaches for multiple acoustic source detection and 2D direction of arrival estimation using a single acoustic vector sensor", IEEE Trans. Signal Processing, 2012.

[4] Xionghu Zhong *et al.*, "A distributed particle filter for acoustic source tracking using an acoustic vector sensor network" in ISSNIP IEEE , pp. 1-5 April 2014

Future tasks

Future	2017		2018								
	Nov	Dec	Jan	Feb	March			Jun	Aug	Sep	Oct
Tasks	1	2	3	4	5	6	7	8	9	10	11
1. Multisource Tracking											
1. RFS + PF + Relativistic											
2. Wind compensation											
3. Implementation											
5. Publications (Journals)											