Tonal and Harmonic Source Localization using Acoustic Vector Sensors

Universidade 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 an unresolved 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: Deetection, source separation and source tracking algorithms for a single AVS.

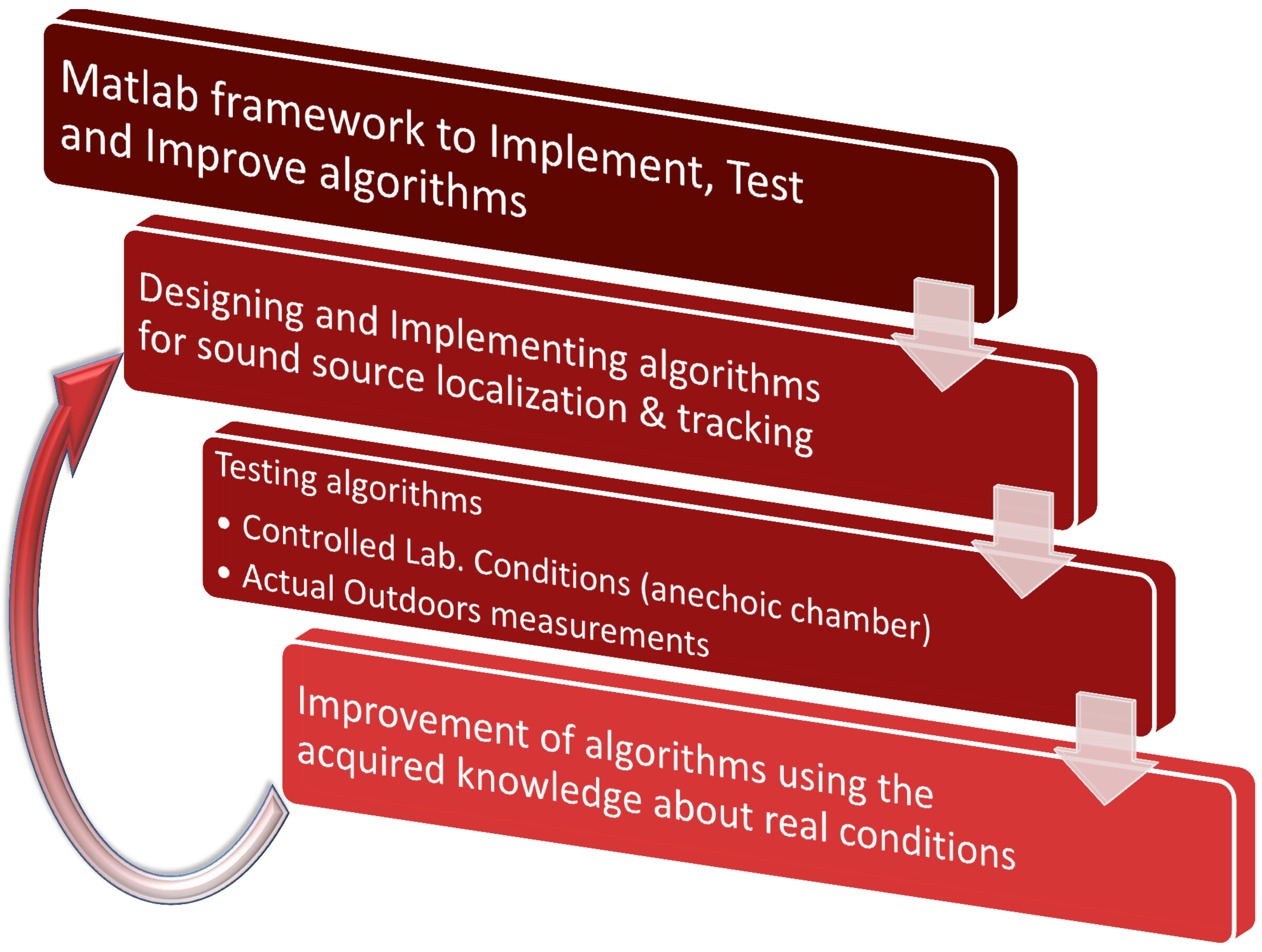
- Central processor: Source localization and tracking algorithms to combine the information collected by the AVS within the network.

Key objectives for this year

- Data gathering.
- Implementation of algorithms to localize and track moving sound sources using a network of AVS.
- Characterization of variables that affect the detection and the localization.
- Design and Improvement of algorithms to account and compensate for effects of real conditions.

METHODOLOGY

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



Different scenarios with different levels of complexity are considered.

RESEARCH PLAN

Developed	2015		2016								
	Nov	Dec	Jan	Feb	March			Jun	Aug	Sep	Oct
Tasks	1	2	3	4	5	6	7	8 (*)	9	10	11
1. Sensor Calibration											
2.Generalization											
3. Implementation											
4. Tests											
5. Multisensor tracking BOT											
5. Publications (Journals)											
Internoise 2016									(*)		

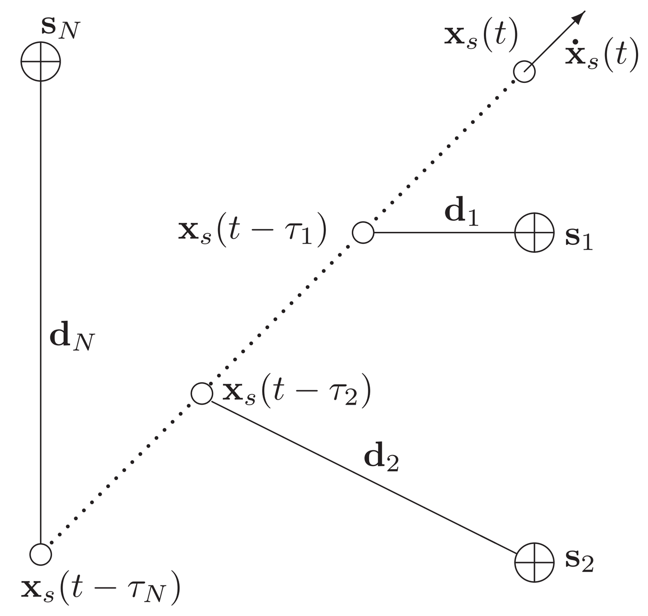
RESULTS AND DISCUSSION

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

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

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

- Constant Velocity (CV) model from $\mathbf{x_s}(t-\tau_i)$ to $\mathbf{x_s}(t)$.



Closed-form solution for the delays ($t \geq t_{\det}$)

$$\tau_i = \frac{\|\mathbf{d}_i\|}{c_0} = \frac{\|\mathbf{x}_s(t) - (\tau_{det}+\tau_i)\dot{\mathbf{x}}_s(t) - \mathbf{s}_i\|}{c_0}$$

$$\tau_i = \frac{-b - \sqrt{b^2-4ac}}{2a}$$

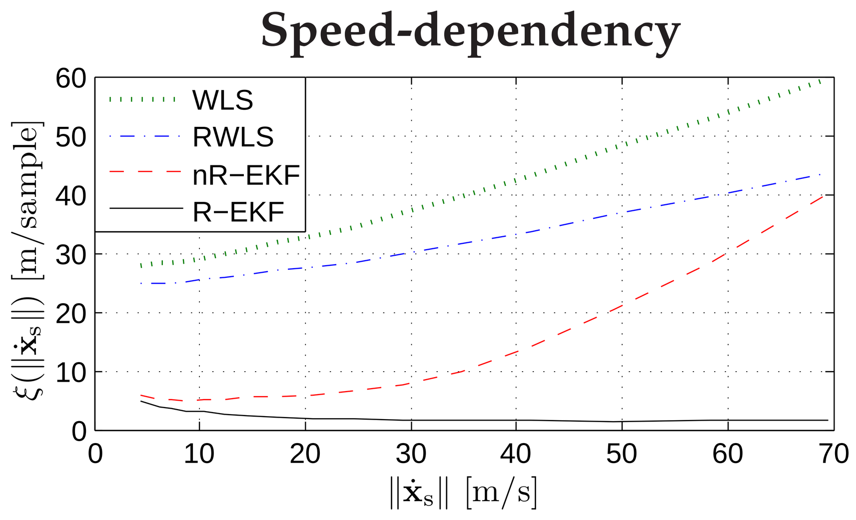
$$a = e - c_0^2\,, \quad b = 2(\tau_{det}e + d)$$

$$c = \|\mathbf{x}_s(t) - \mathbf{s}_i\|^2 + \tau_{det}(\tau_{det}e + 2d)$$

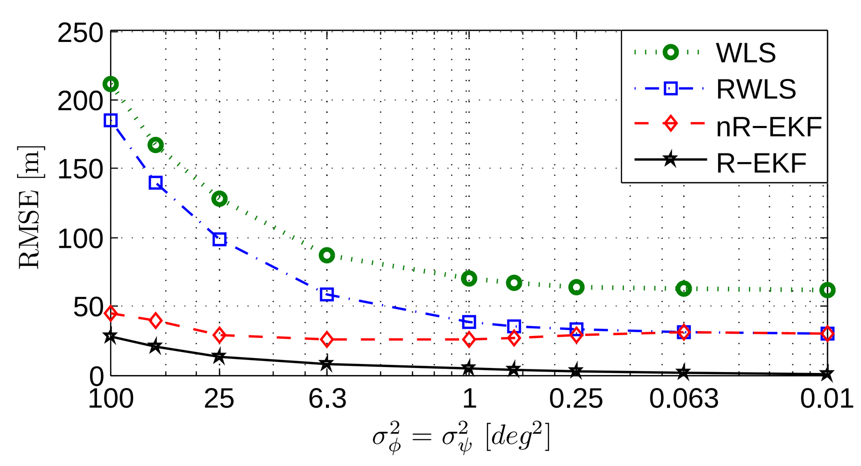
$$d = -\dot{\mathbf{x}}_s^T(t)(\mathbf{x}_s(t) - \mathbf{s}_i)\,, \quad e = \|\dot{\mathbf{x}}_s(t)\|^2$$

- Relativistic 1^{st}-order Extended Kalman Filter based on the proposed model. Compared to its non-relativistic counterpart.

Speed-dependency



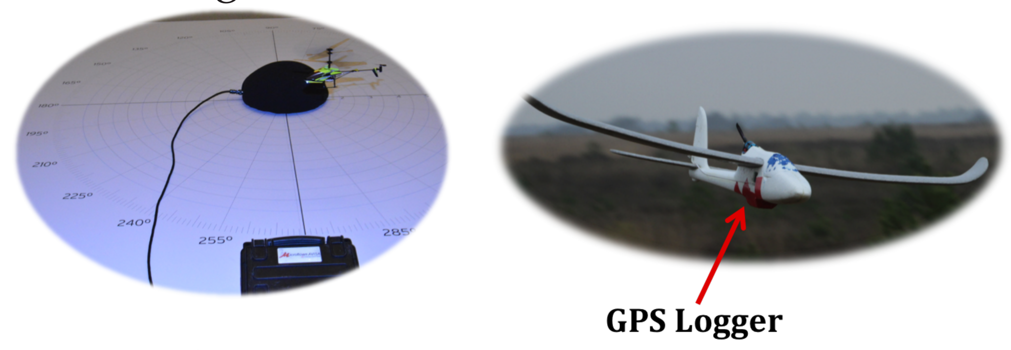
Performance



- Speed-independent performance for the range of speeds of interest.
- Unlike other approaches, the relativistic EKF leads to an unbiased tracking algorithm if the source moves at constant speed.

OUTCOMES (TO DATE)

- Extensive measurements have been performed under controlled and outdoors conditions using RC aircrafts.



- Euronoise 2015 Conference Paper: David P. Cabo *et al.* *"Real Life Harmonic Source Localization Using a Network of Acoustic Vector Sensors"*
- 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"*
- IEEE Transactions on Signal Processing Journal Paper: David P. Cabo *et al.* *"Relativistic Acoustic Source Tracking using Bearing-Only Measurements in a Wireless Network of Acoustic Vector Sensors"* (in peer review)

REFERENCES

[1] M. Hawkes *et al.*, "Acoustic Vector Sensor Beamforming and CAPON direction estimation", IEEE Trans. Signal Processing, vol. 46, pp 2291-304, Sept. 1998.
[2] 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.
[3] M. Hawkes *et al.*, Wideband Source Localization Using a Distributed Acoustic Vector-Sensor Array. IEEE Transactions on signal processing , Vol. 51, NO. 6, pp. 1479-1491, June 2003
[4] D. Levin *et al.*, "Direction of Arrival Estimation using acoustic vector sensors in presence of noise", ICASSP 2011.
[5] 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, vol. 60, no. 9, pp. 4719-33, 2012.
[6] 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	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)											