Tonal and Harmonic Source Localization using Acoustic Vector Sensors

Universidade de Vigo

David Pérez Cabo, Microflown AVISA, cabo@microflown.com
Advisors: Manuel Sobreira Seoane, Universidade de Vigo, msobre@gts.uvigo.es
Hans Elias de Bree, Microflown AVISA, debree@microflown.com

Microflown AVISA — 3D Acoustic Situational Awareness

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Motivation

With the number of non-controlled flying or 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

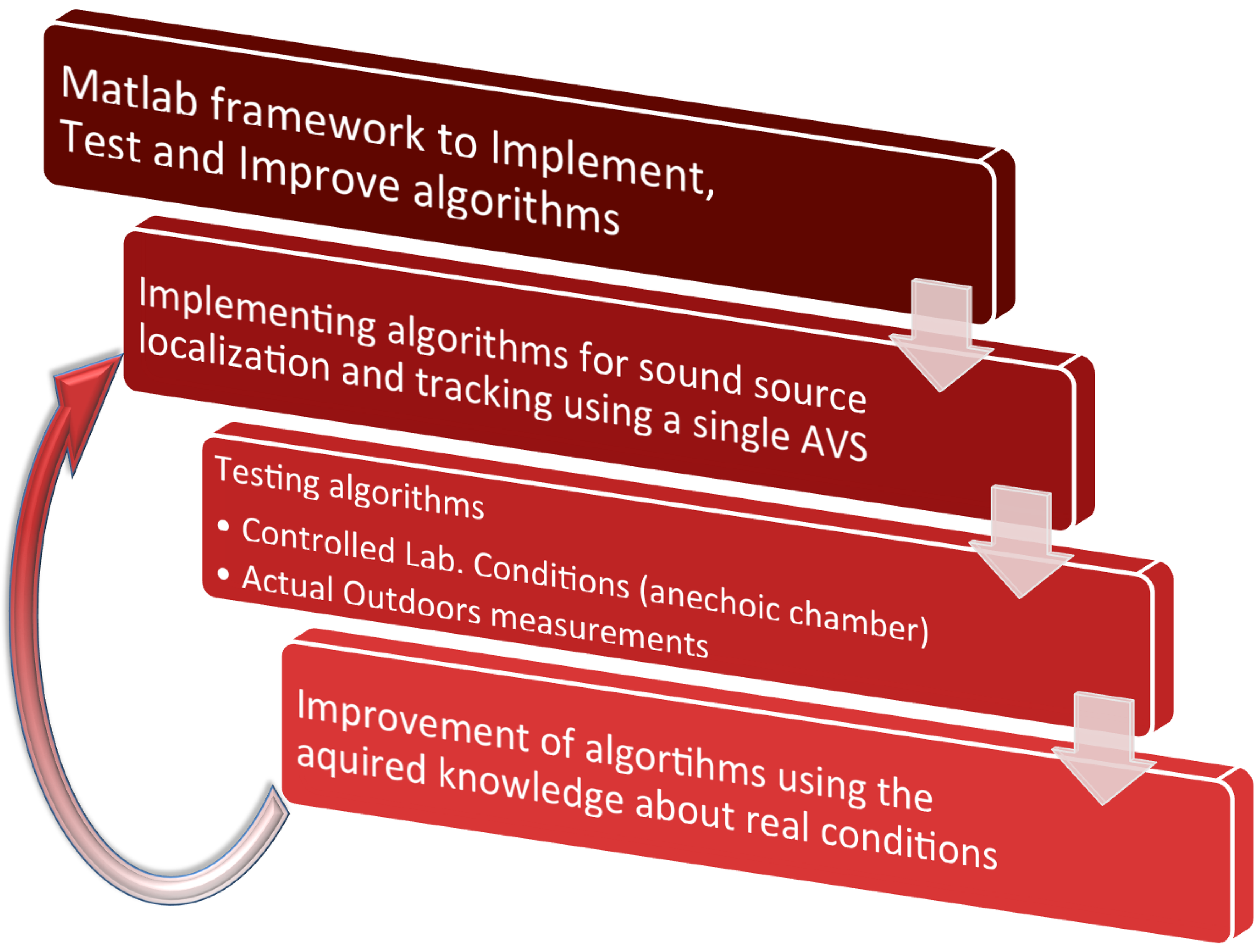
The main objective of the thesis is to develop a framework for detecting, localizing and tracking tonal or harmonic sources using a distributed network of acoustic vector sensors.The goal of its initial stage is to apply to real measurements all the existent algorithms for localizing the DOA of moving sources using an Acoustic Vector Sensor, and design new methods that exploit the spectral structure of that kind of sources and the sensor characteristics.

Key objectives for this year

- Obtaining a set of laboratory and real measurements.
- Implementation of algorithms to localize and track the DOA of moving sound sources with a single 2D or 3D sensor.
- Study variables that can affect the detection and the localization (propagation effects, non-stationary sound sources and background noise,...).
- 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 available in the literature, and maybe others.



Different scenarios with different levels of complexity will be considered.

Research Plan

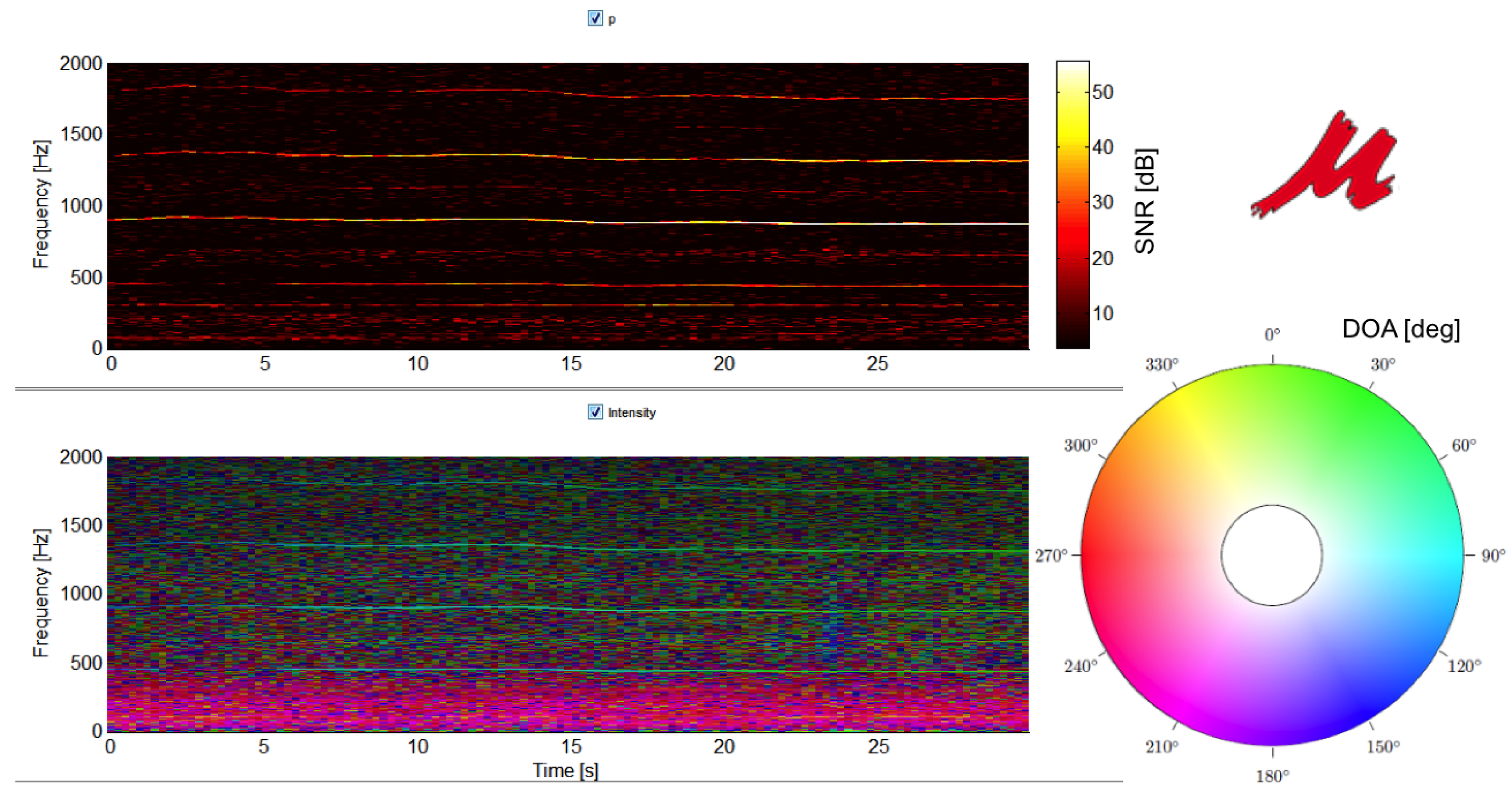
Developed	2014		2015								
	Nov	Dec	Jan	Feb	March			Jun	Aug	Sep	Oct
Tasks	1	2	3	4	5	6	7	8 (*)	9	10	11
1. State of Art											
2.Design of framework											
3. Measurement Plan											
4. Implementation											
5. Tests											
EURONOISE 2015								(*)			
6. Adapt. Algorithms											

Results

- Measurement Model for Far Field DOA (N sensors located at $\mathbf{r_i}$).

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

- Analysis and visualization features have been added to the framework.

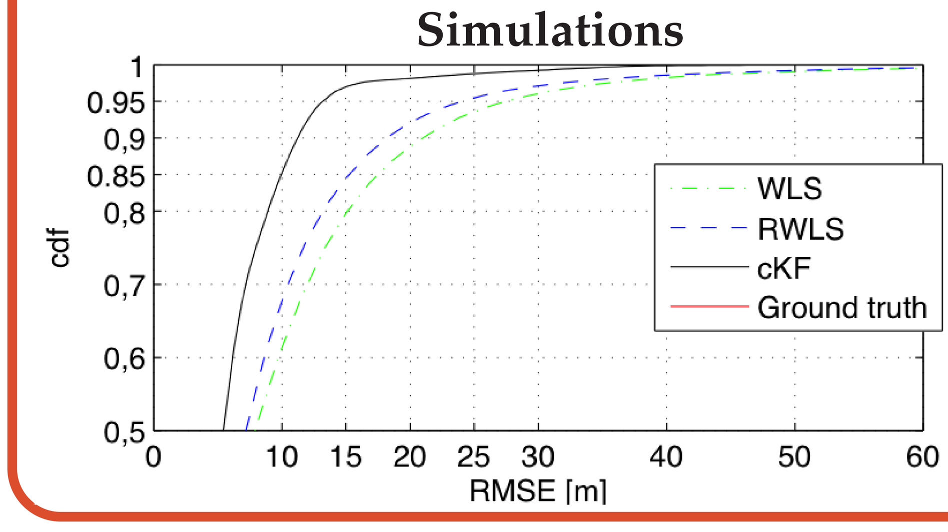


- Successful 2D Proof-Of-Concept of a network solution using a Kalman Filter to model the source motion and CAPON method to estimate the DOA.

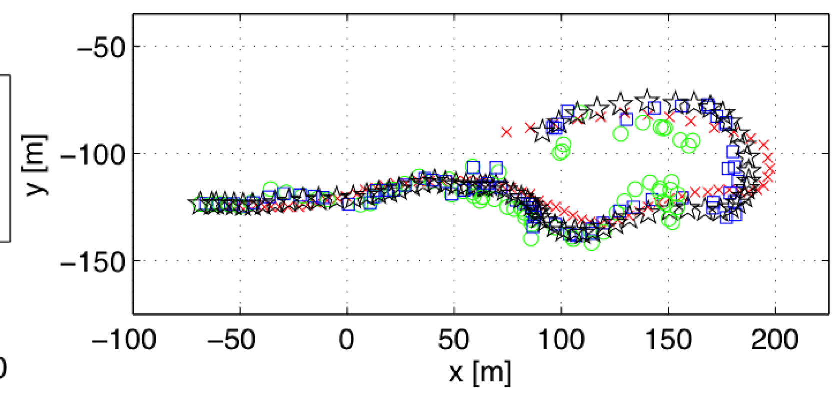
$$\hat{\boldsymbol{\theta}} = \left[\left(\sum_{i=1}^{N_s} w_i \right) I - \hat{U} W \hat{U}^T \right]^{-1} A\mathbf{w}, \quad \begin{matrix} \hat{U} = [\hat{\mathbf{u}}_1, ..., \hat{\mathbf{u}}_{N_s}] \\ \mathbf{w} = [w_1, ..., w_{N_s}]^T \end{matrix} \quad \begin{matrix} \omega_{i,WLS} = MSAE(\hat{\mathbf{u}}_\mathbf{i}) \\ \omega_{i,RWLS} = \omega_{i,WLS}/\hat{l}_i \end{matrix}$$

$$A = \left[(I - \hat{\mathbf{u}}_1 \hat{\mathbf{u}}_1^T) p_1, ..., (I - \hat{\mathbf{u}}_{N_s} \hat{\mathbf{u}}_{N_s}^T) p_{N_s} \right] \qquad if\ \mathbf{e_i} = 0 \ \Rightarrow \ \mathbf{r_i} + l_i \mathbf{u_i} = \boldsymbol{\theta}$$

Simulations

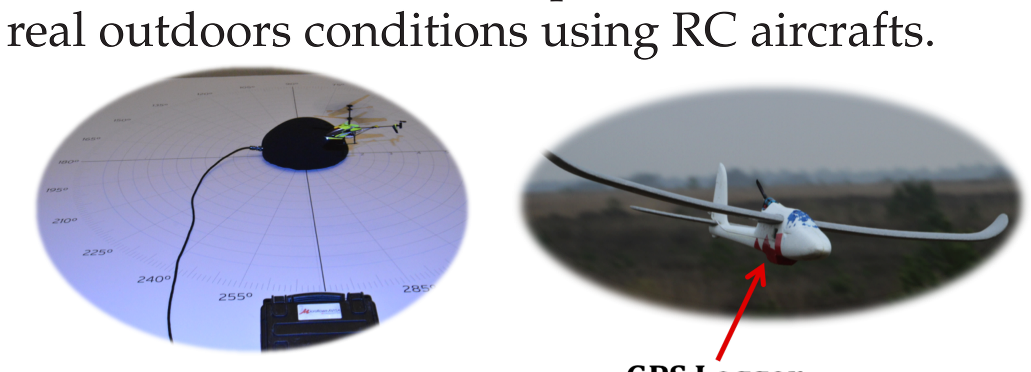


Field Measurements



Outcomes (to date)

- The Matlab framework to **Implement**, **Test**, and **Improve** algorithms (**ITI** framework) has been designed. The algorithms available in the literature are being implemented within the ITI framework.
- Extensive measurements have been performed under controlled conditions and under real 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"*

References

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[3] Hawkes, M., Nehorai, A., 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

[4] D. Levin, E. A. P. Habets and S. Gannot, "Direction of Arrival Estimation using acoustic vector sensors in presence of noise", ICASSP 2011.

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Future tasks

Future	2015		2016								
	Nov	Dec	Jan	Feb	March			Jun	Aug	Sep	Oct
Tasks	1	2	3	4	5	6	7	8 (*)	9	10	11
1.Adapt. Algorithms											
2.Generalization											
4. Implementation											
5. Tests											
6. Netwroked approach											
Internoise 2016									(*)		