Acoustics '17 Boston
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Analysis of the feasibility of using an array of MEMS microphones to machinery condition monitoring or fault diagnosis

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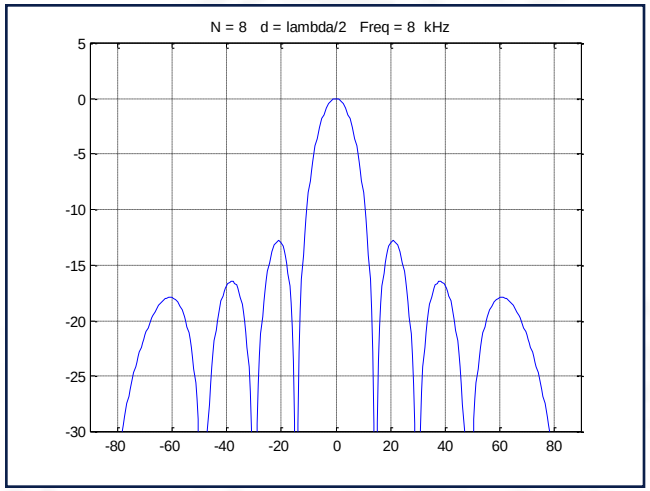
- Introduction
- Material and Methods
- Results
- Conclusions

Introduction

- Traditionally, vibration analysis to evaluate condition monitoring and fault diagnosis of mechanical systems
- **Problem:** sensors in contact with the vibrant surfaces
- **Solution:** analysis of the acoustic signals directly related with the vibrations
- Use of arrays of MEMS microphones to obtain acoustic signals

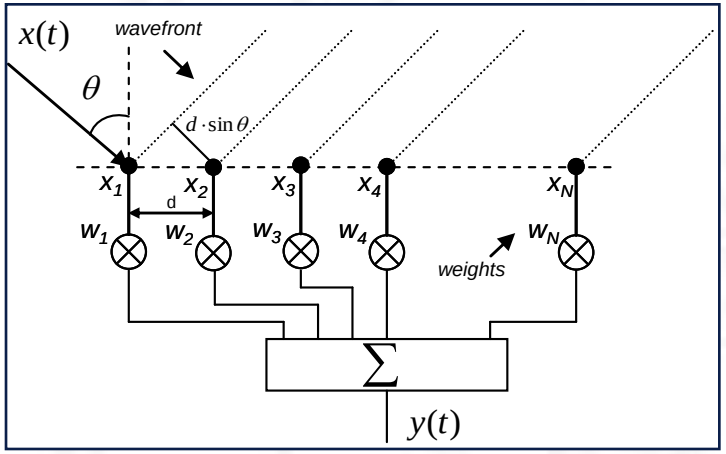
Introduction

- An array is an arranged set of identical sensors.
  - Beampattern controlled by modifying geometry, sensor spacing and amplitude and phase excitation of sensors



Introduction

- An array is an arranged set of identical sensors.
  - Beampattern controlled by modifying geometry, sensor spacing and amplitude and phase excitation of sensors
  - Beamforming techniques steer electronically the array beampattern to different spatial positions



Introduction

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- MEMS (Micro-Electro-Mechanical System)

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- MEMS, technology for the miniaturization of mechanical sensors

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- **Arrays of MEMS microphones**

High-quality microphones:
- High SNR
- Low power consumption
- High sensitivity

Introduction

- An array is an arranged set of identical sensors.
- MEMS, technology for the miniaturization of mechanical sensors
- **Arrays of MEMS microphones**
  - Initially designed for acoustic source localization
  - High diversity applications → Acoustical Imaging

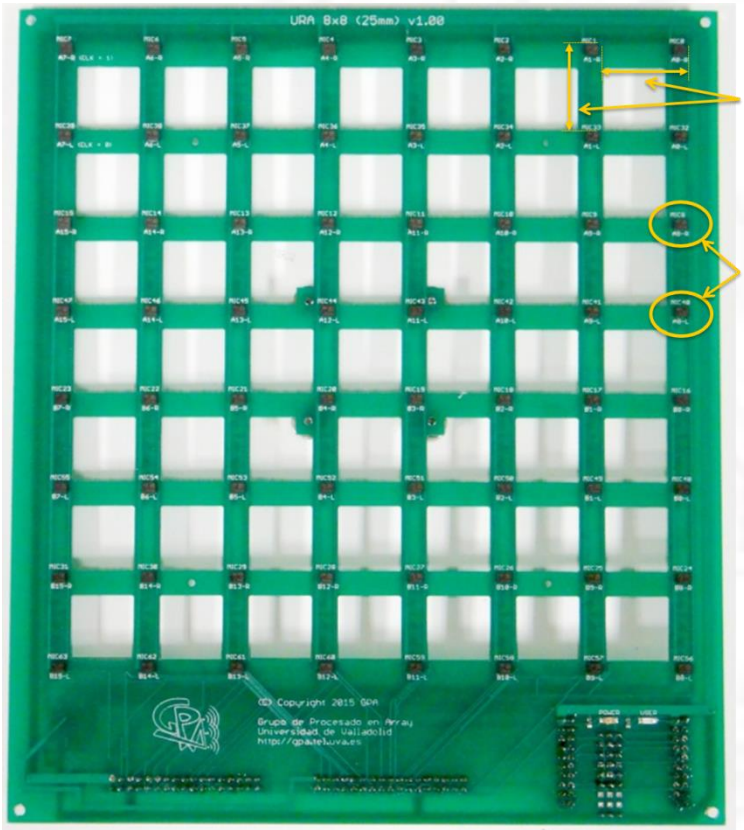
Introduction

- An array is an arranged set of identical sensors.
- MEMS, technology for the miniaturization of mechanical sensors
- **Arrays of MEMS microphones**
  - Initially designed for acoustic source localization
  - High diversity applications → Acoustical Imaging
- This work: **new application**
  - Acquisition and processing of acoustic images of a fan matrix for its **condition monitoring** and **fault diagnosis**

Material and Methods

- Acoustic images acquisition system:
  - **Array** of digital **MEMS** microphones

Working frequency range: 40Hz – 16kHz



MP34DT01
STMicroelectronics
- PDM interface
- Low-power
- Omnidirectional
- 63dB SNR
- High sensitibity

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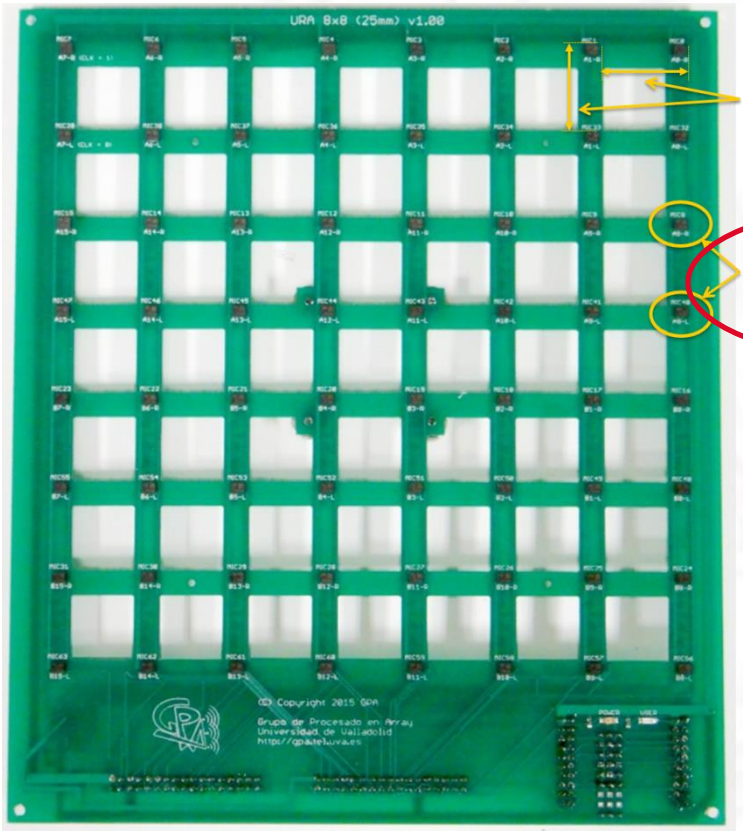

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Material and Methods

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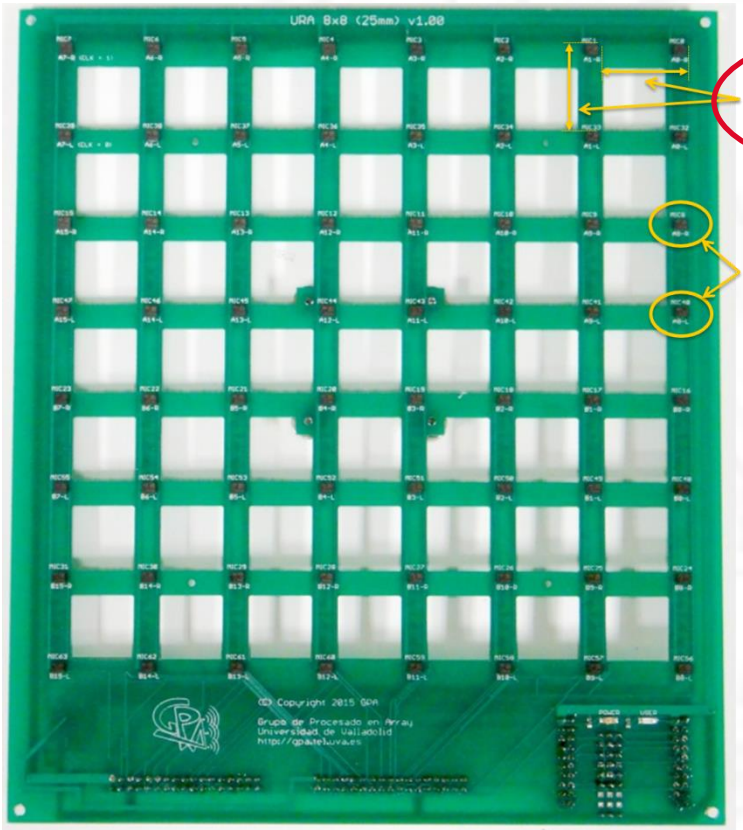
2.125cm = 8kHz λ/2



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Material and Methods

- Acoustic images acquisition system:
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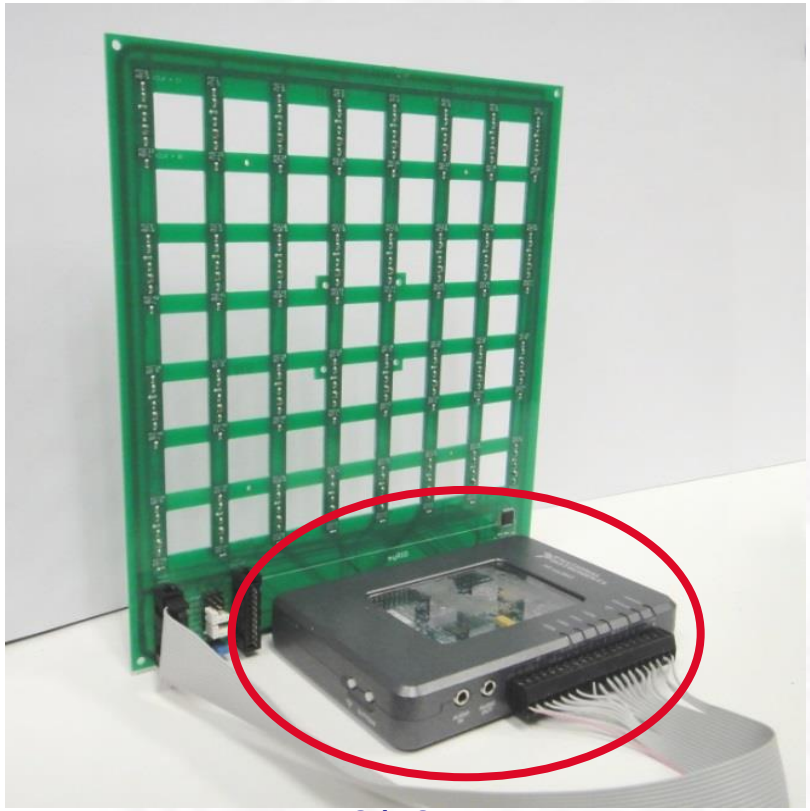
  - **myRIO** platform, base unit of the system



FPGA-based

Material and Methods

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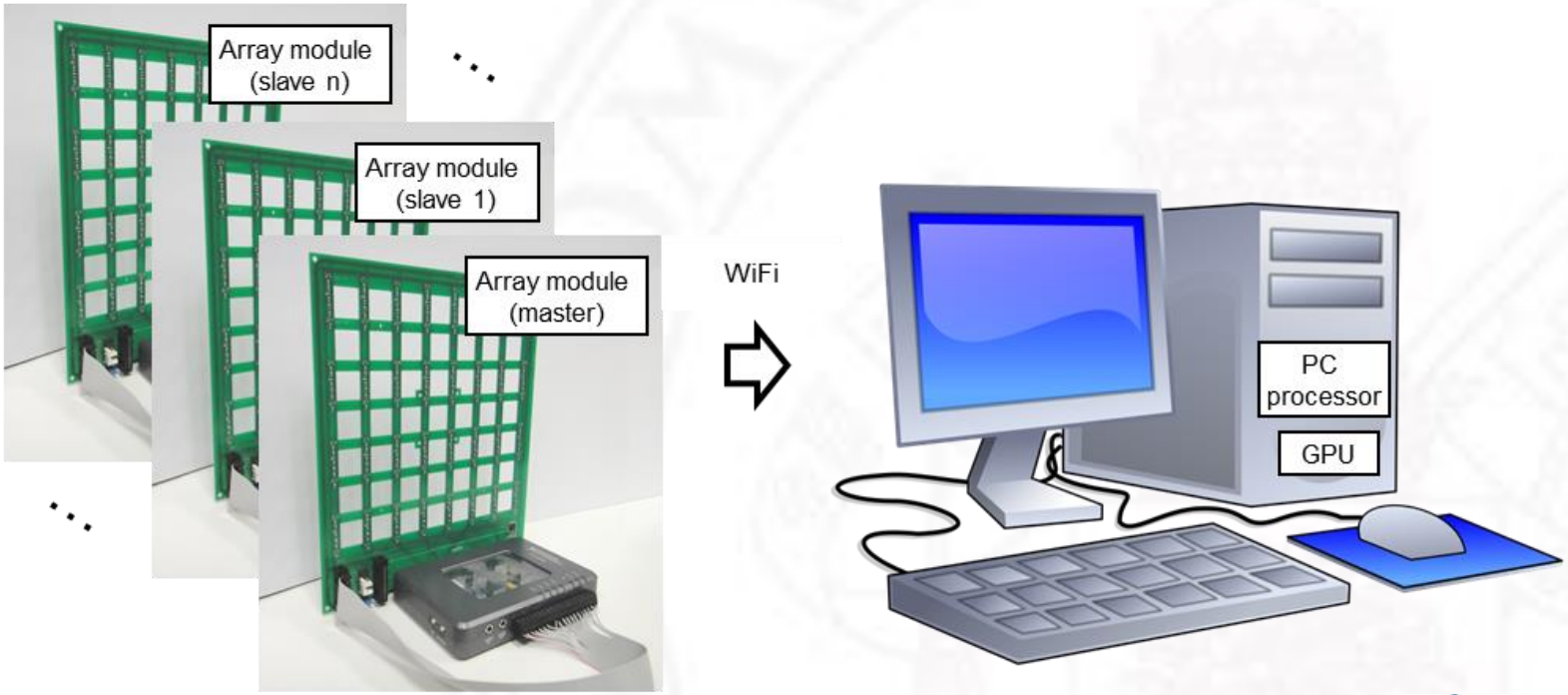
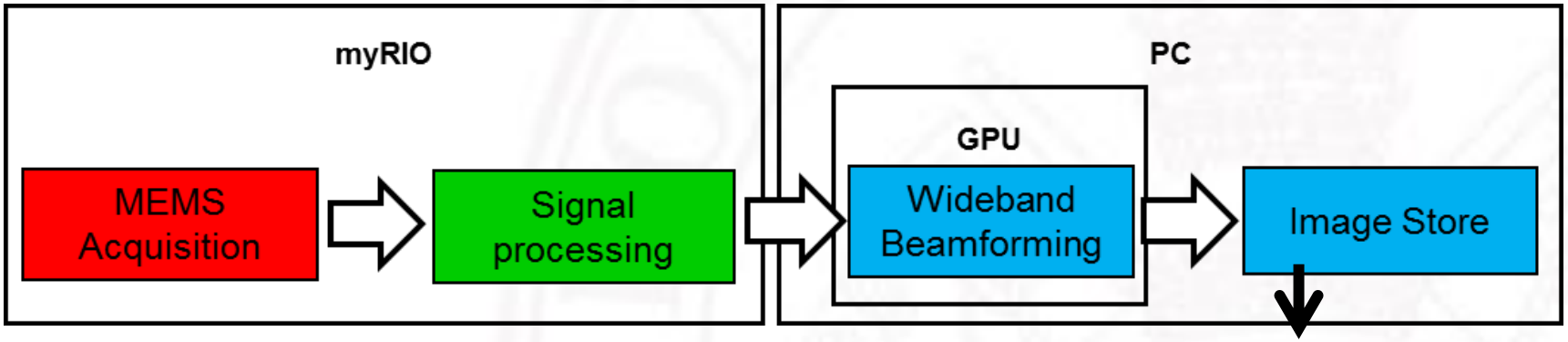


Material and Methods

- Acoustic images acquisition system:
  - **Array** of digital **MEMS** microphones
  - **myRIO** platform, base unit of the system
  - **Processing platform**



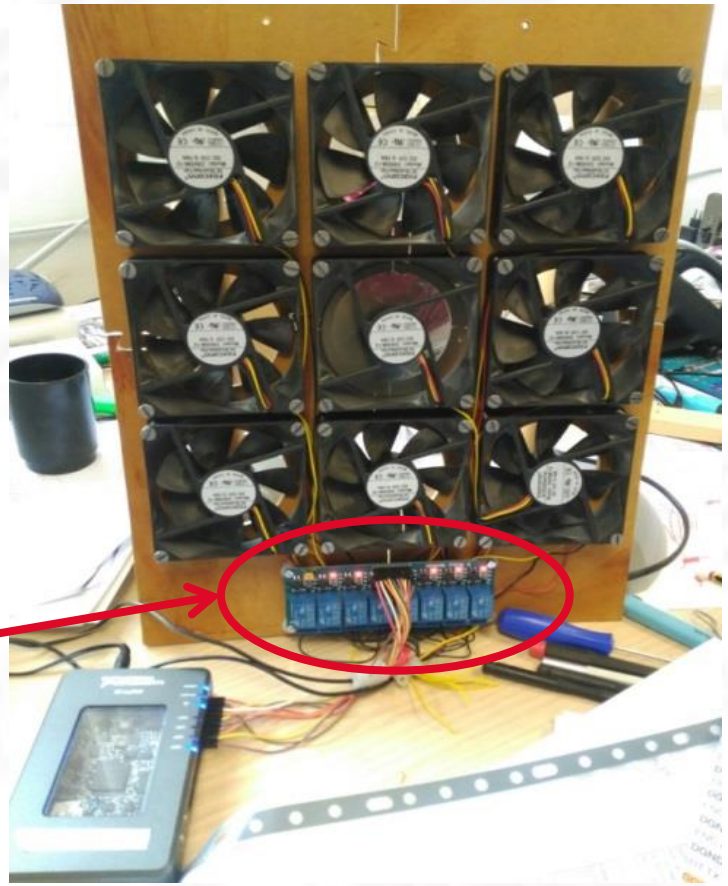
4D acoustic images:
- Azimuth
- Elevation
- Range
- Frequency

Material and Methods

- Test **fan matrix**:

Axial PC fans

9 (3x3) fans



Interface board

Switch on and off each fan

Simulate working and faulty fans

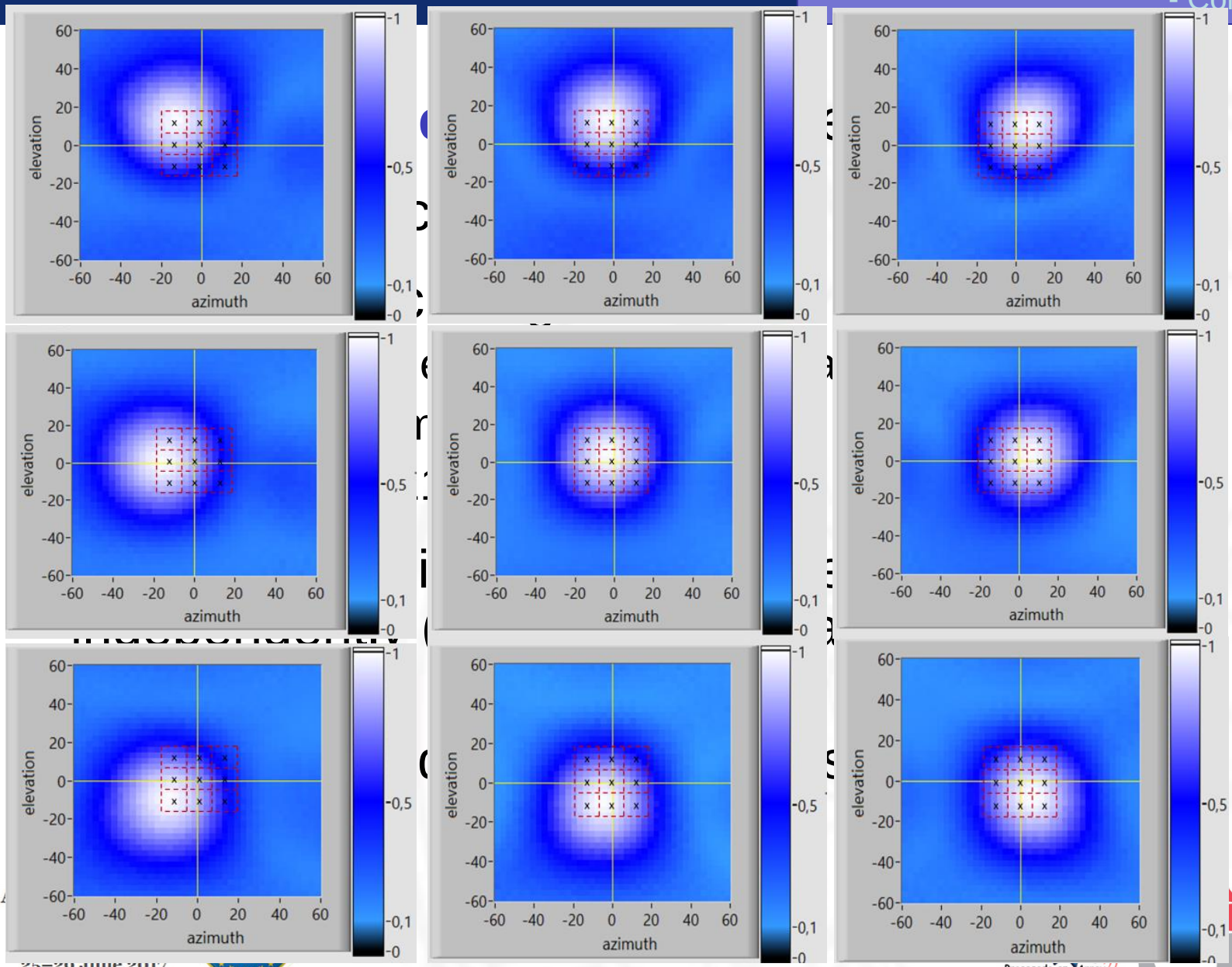
Results

- **Acoustic images** of independent fans:
  - Hemianechoic chamber
  - Each acoustic image:
    - Azimuth and elevation: 41 x 41 values in [-60º, 60º]
    - Range: 30 cm
    - Frequency: 1100 Hz (harmonic)
  - 9000 acoustic images: 1000 of each fan running independently (non-stationary fan noise)

⬇

Averaged acoustic images

Results



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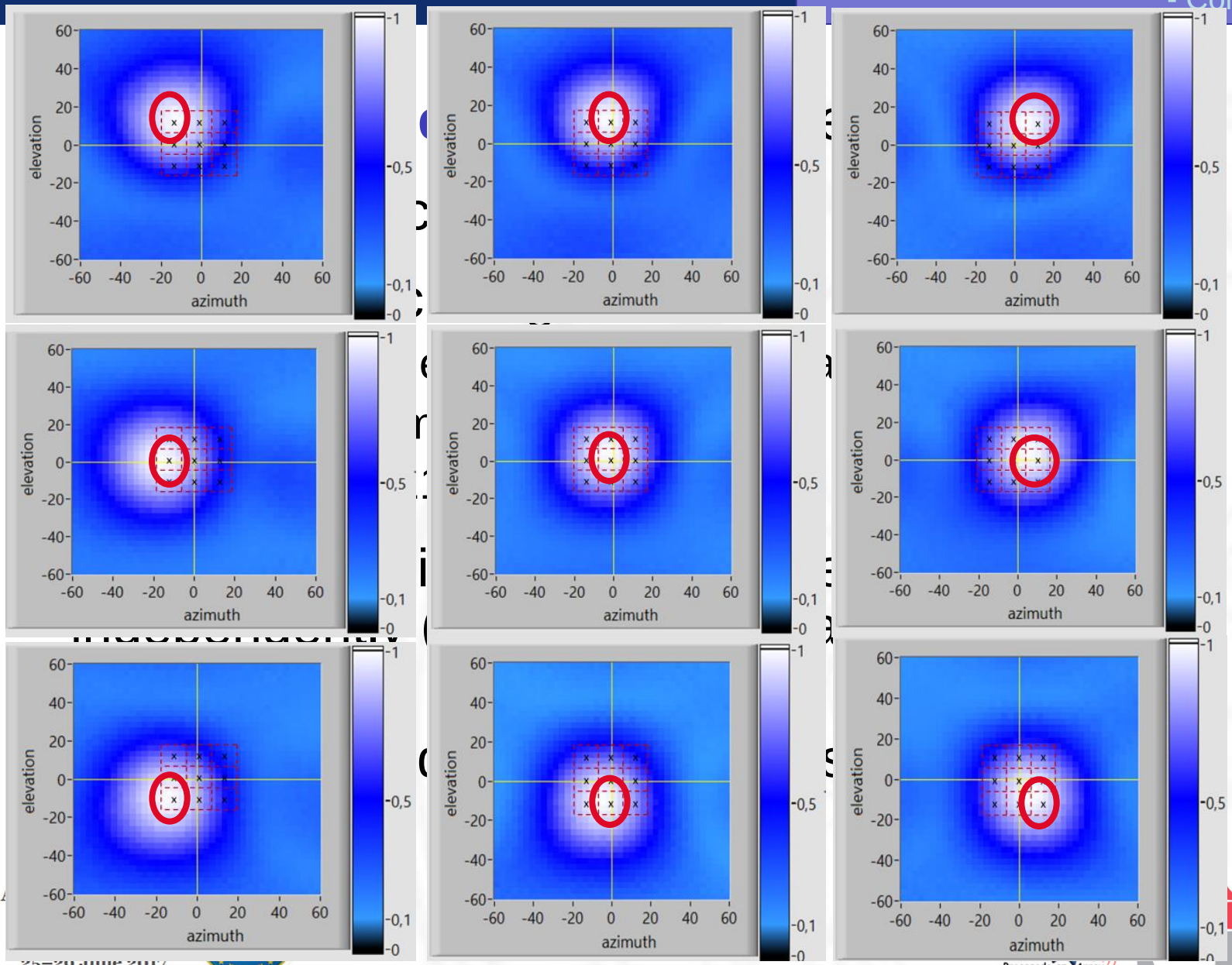

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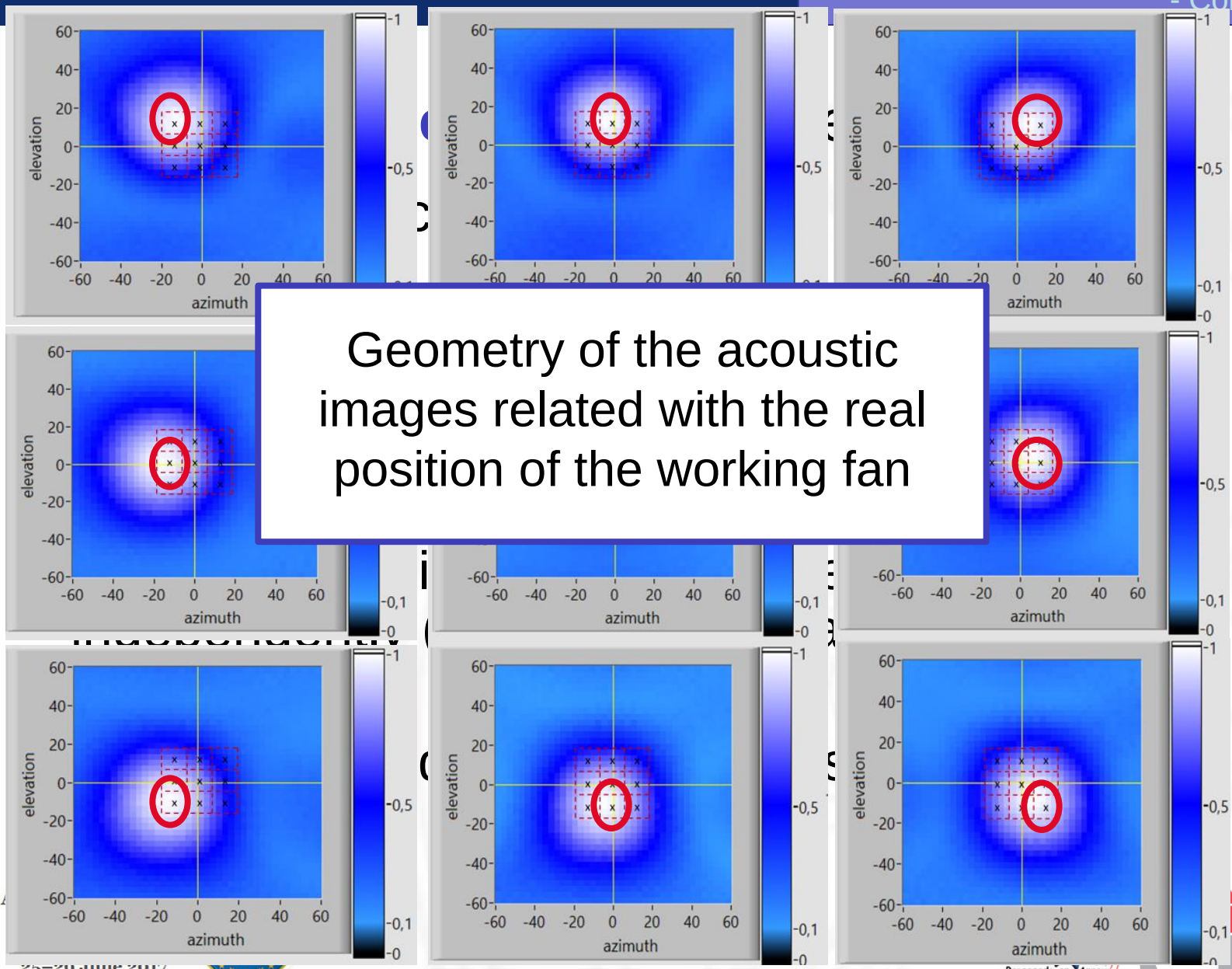
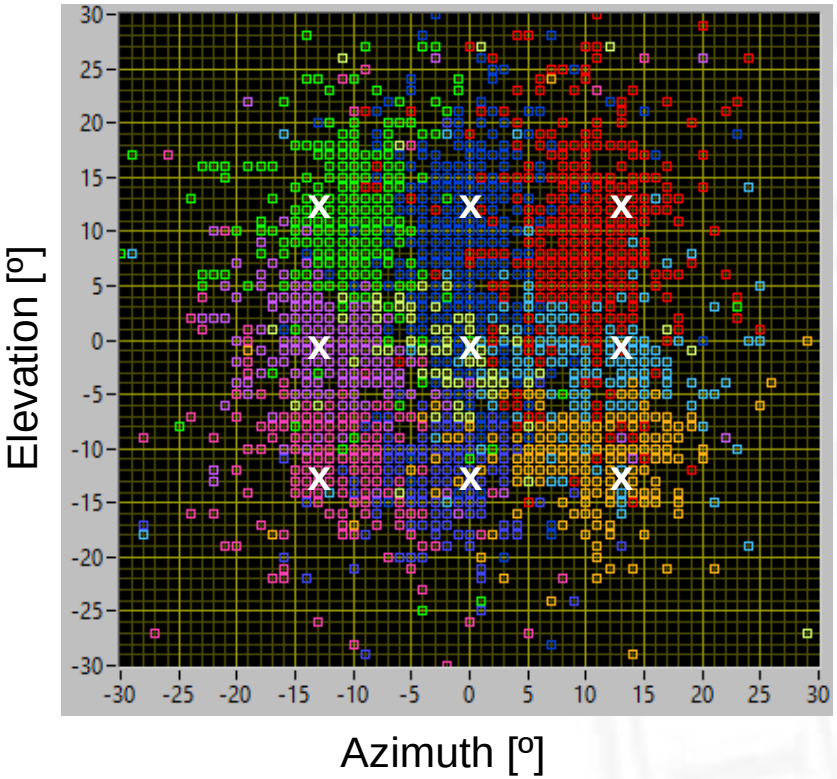


Geometry of the acoustic images related with the real position of the working fan

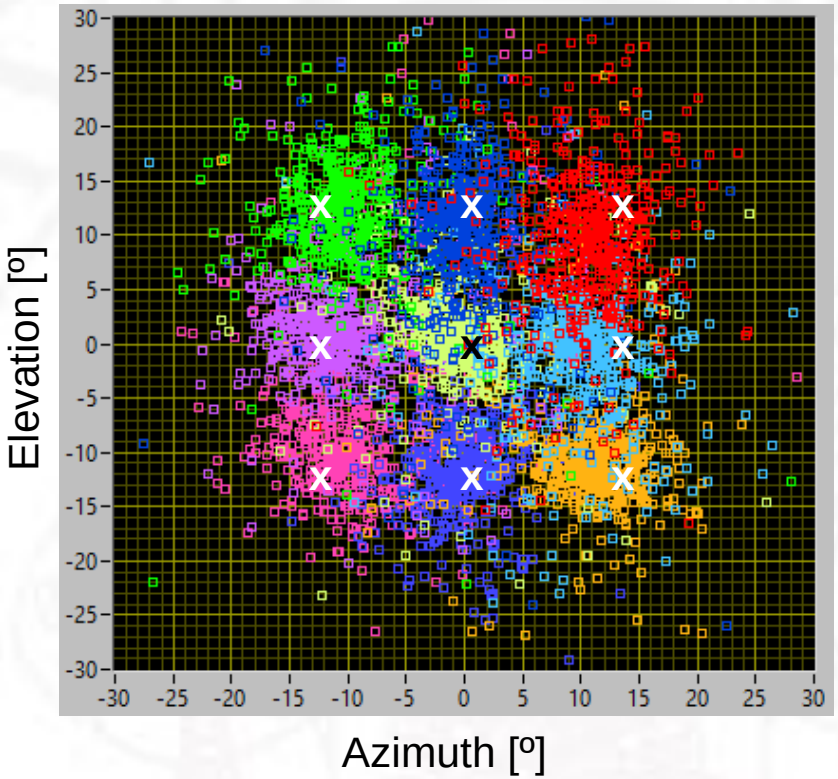
Results

- **Geometrical parameters extraction**

Maximum positions



Centers of mass positions



Results

- **SVM classification**, using RBF kernel:
  - Objective: Detect the running fan

Information	Dimension
Whole acoustic images	1681
Parameters of acoustic images:	
Maximum	2
Centres of mass	2
Maximum + centres m.	4

Results

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Results

- **SVM classification**, using RBF kernel:
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Whole acoustic images	1681	**75,30%**
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Maximum + centres m.	4	

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Whole acoustic images	1681	**75,30%**
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Maximum + centres m.	4	**21,44%**

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Whole acoustic images	1681	**75,30%**
Parameters		
Maxi		**34,78%**
Cent		**32,84%**
Maxi		**21,44%**

Geometrical parameters reveal useful information for the classification

Conclusions

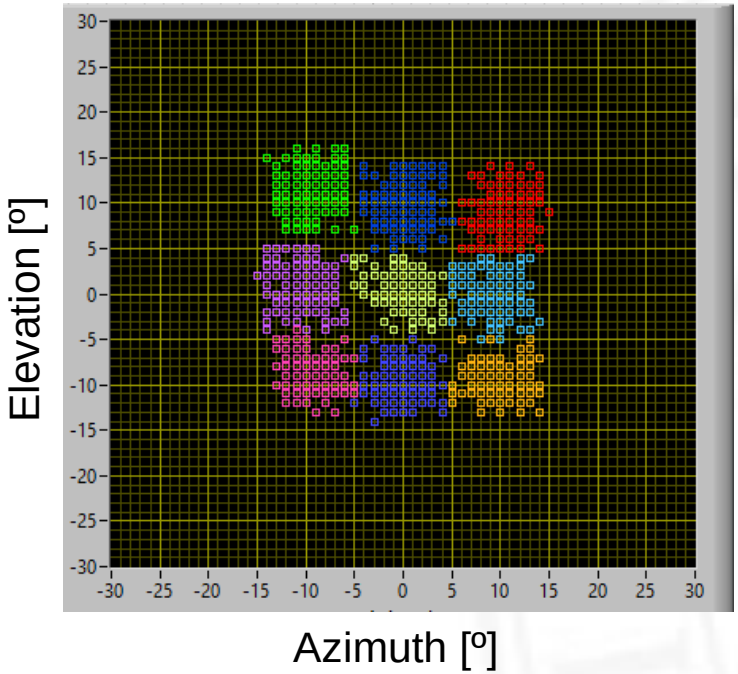
- Acoustic images of individual fans to estimate their real positions inside the matrix
- SVM classification:
  - The whole acoustic images are not useful
    → High error rate.
  - Geometrical parameters of the acoustic images
    → Useful information for classification

First step to detect faulty fans on the fan matrix

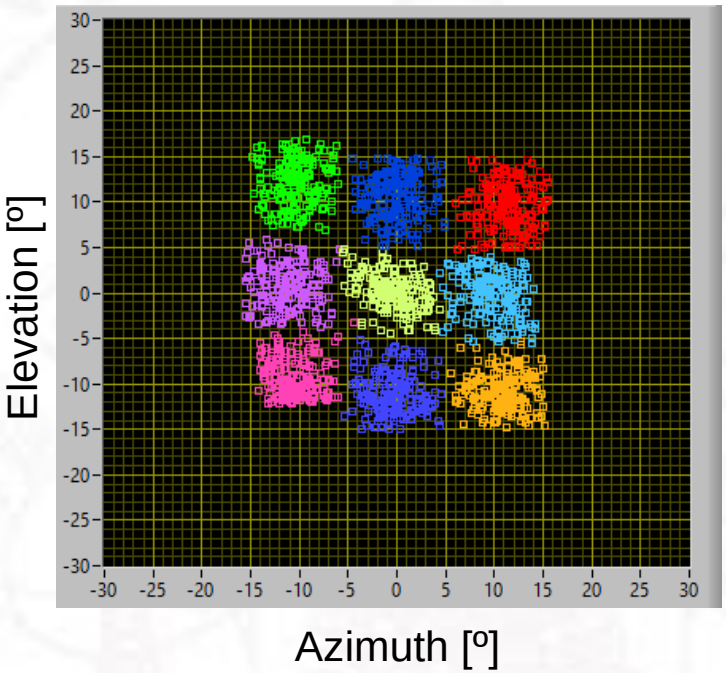
Future work

- Improve acoustic image capture
  - Objective: lower parameter dispersion

Maximum positions



Centers of mass positions



Future work

- Improve acoustic image capture
  - Objective: lower parameter dispersion
- Extract more parameters of acoustic images
  - Azimuth and Elevation
  - Range
  - Frequency

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- Improve acoustic image capture
  - Objective: lower parameter dispersion
- Extract more parameters of acoustic images
  - Azimuth and Elevation
  - Range
  - Frequency
- Repeat tests considering all fans working instead of one (one faulty fan)

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Thanks for your attention

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