Noise robust 2D bird localization via sound using microphone arrays

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1. Ornithology

Bird song analysis

- When, where, what, how information
- Obtained manually

Drawbacks

- A tough and difficult task
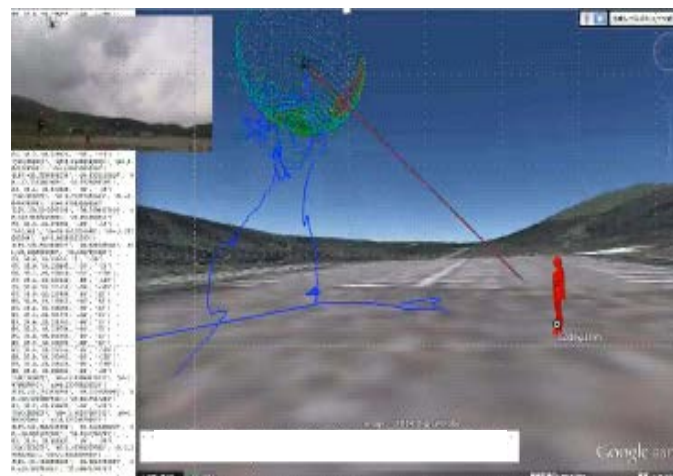- Limited by experience
- Prone to misinterpretations

2. Robotics

Robot audition

- Real time processing using microphone arrays
- Effective in noisy environments

Drawbacks

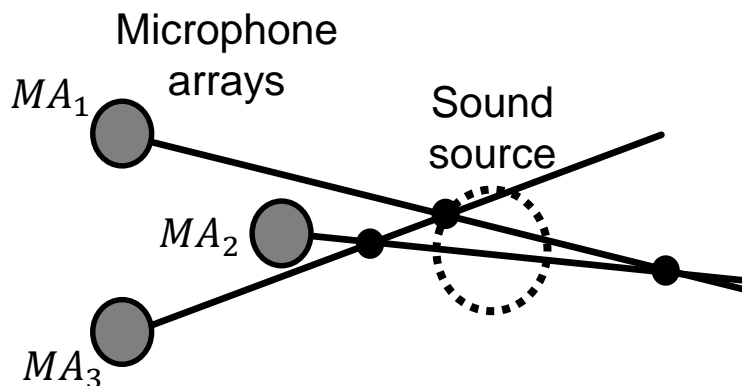- Mostly only DoA (Direction of Arrival) estimation performed

Applying multiple microphone arrays to obtain 2D/3D sound source positions
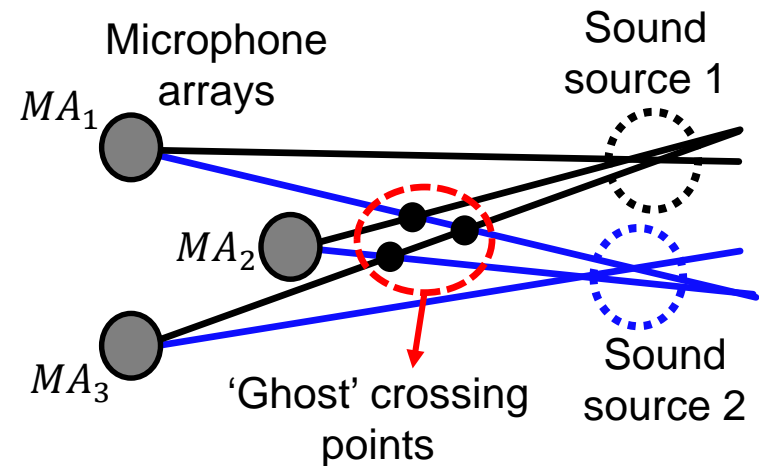
2D localization difficulties

1. **Directions do not cross in one point**
   - Caused by noise
   - Estimate the location from 3 crossing points

2. **'Ghost' crossing points (outliers)**
   - Multiple sound sources localized at the same time
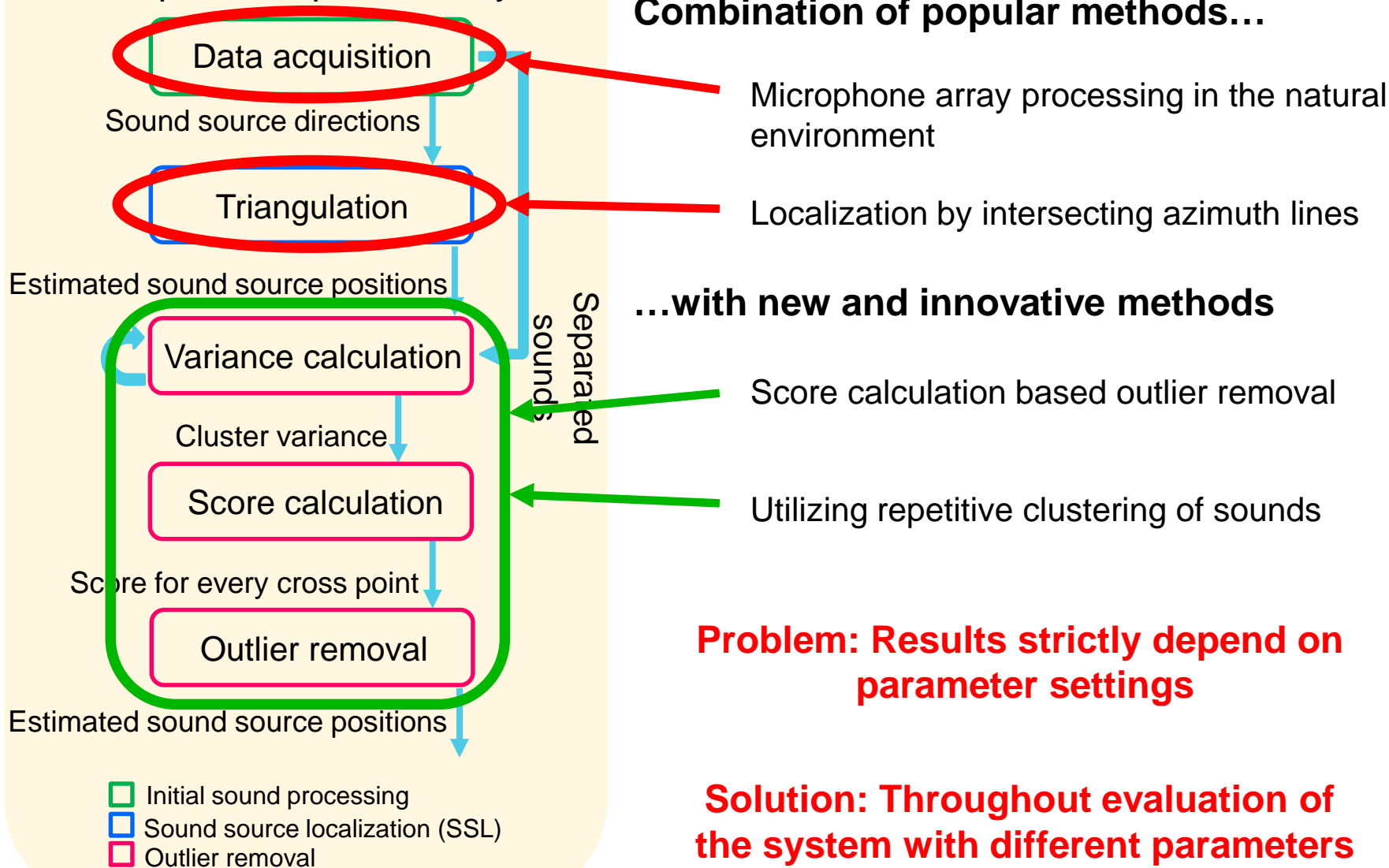   - Must be removed

Solutions to these problems:
1. Performing center of gravity (CoG) calculation
2. Introduction of an outlier removal method

Flow of the algorithm for SSL with multiple microphone arrays

Data acquisition

Sound source directions

Triangulation

Estimated sound source positions

Variance calculation

Cluster variance

Score calculation

Score for every cross point

Outlier removal

Estimated sound source positions

Separated sounds

☐ Initial sound processing
☐ Sound source localization (SSL)
☐ Outlier removal

Combination of popular methods…

Microphone array processing in the natural environment

Localization by intersecting azimuth lines

…with new and innovative methods

Score calculation based outlier removal

Utilizing repetitive clustering of sounds

Problem: Results strictly depend on parameter settings

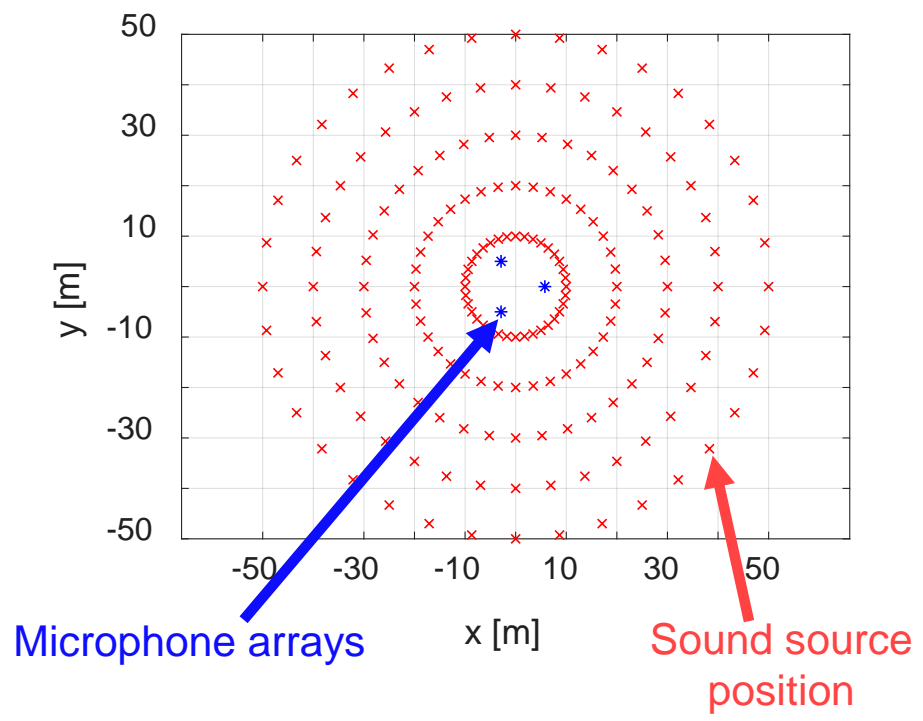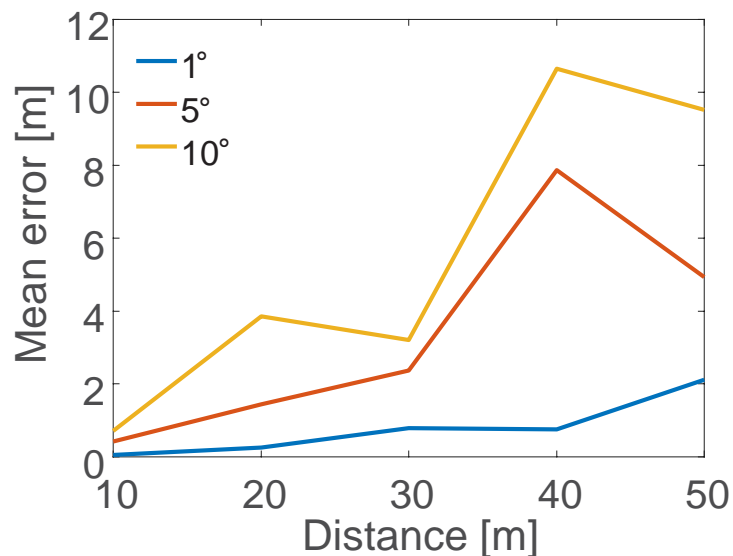**Solution: Throughout evaluation of the system with different parameters**

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Parameters:

- Transfer Function resolution

- Number of microphone arrays

- Signal-to-Noise Ratio (SNR)

- Three bird types:

    - Eastern Crowned-Warbler
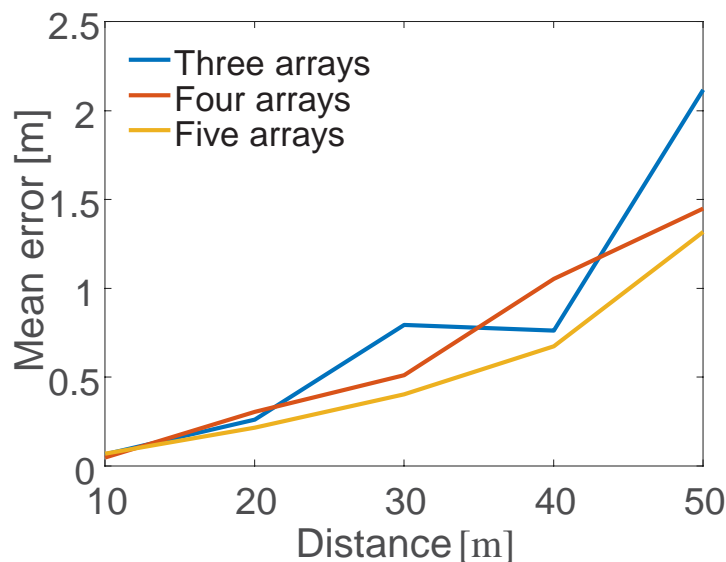
    - Japanese Bush Warbler
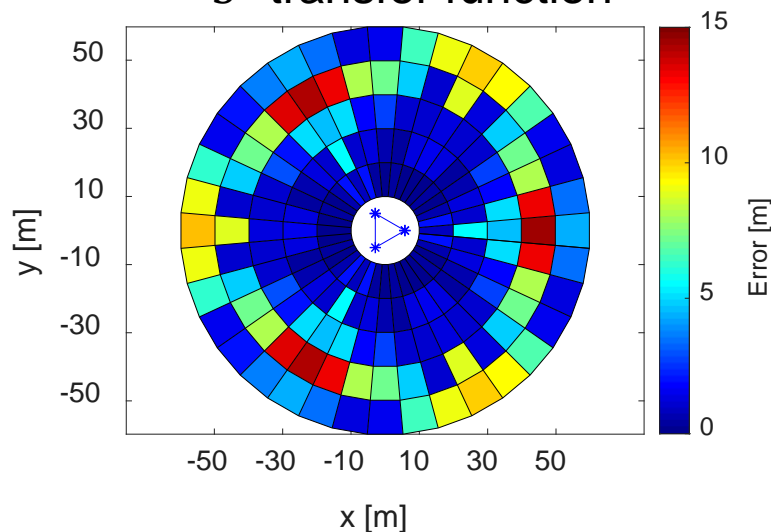
    - Narcissus Flycatcher

Evaluation scene:

Microphone arrays

Sound source position

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Transfer Function resolution

Number of microphone arrays
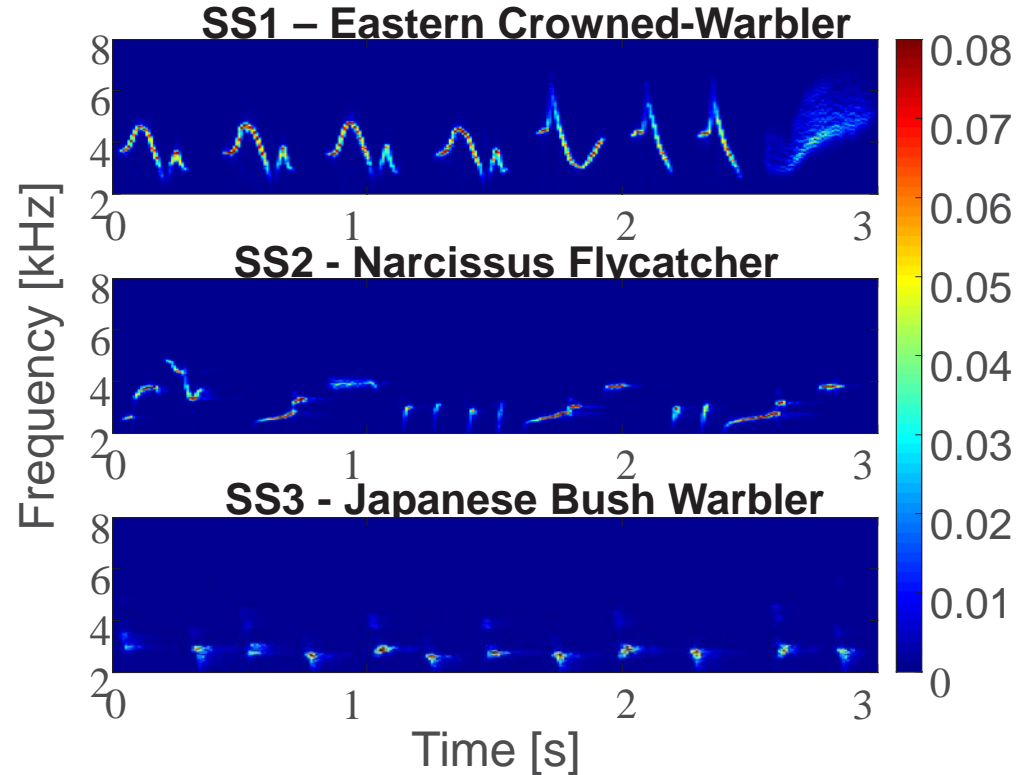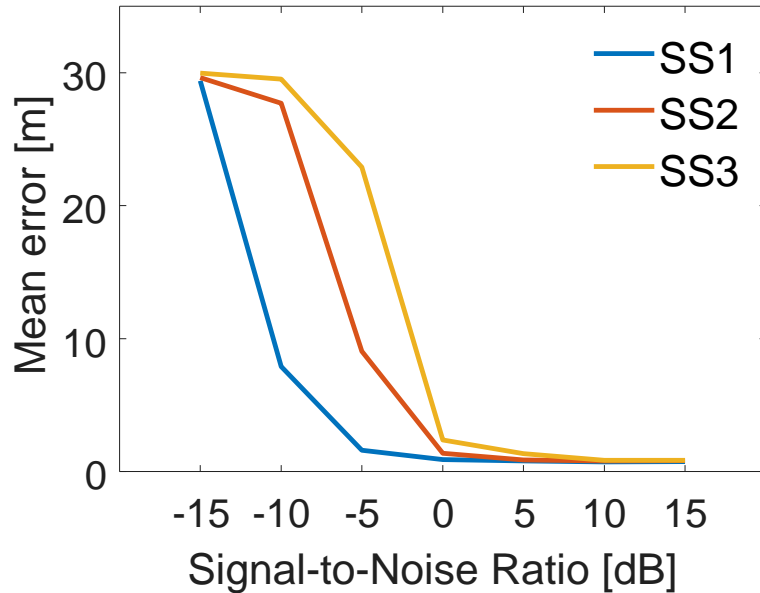

5° transfer function

Transfer Function:
- Minimal error at 50 m is ~2 m for 1° transfer function
- Overall better accuracy with higher resolution

Number of arrays:
- Similar performance for all cases
- Accuracy and computing power tradeoff

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Signal-to-Noise Ratio and bird types

SS1 – Eastern Crowned-Warbler

SS2 - Narcissus Flycatcher

SS3 - Japanese Bush Warbler

- Up to 0dB the system can localize all three birds with low error
- -5dB and -10dB: performance dependent on the bird type

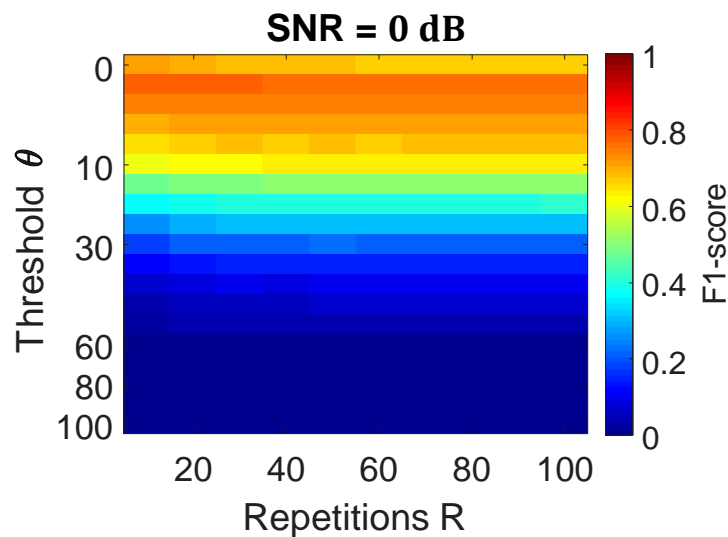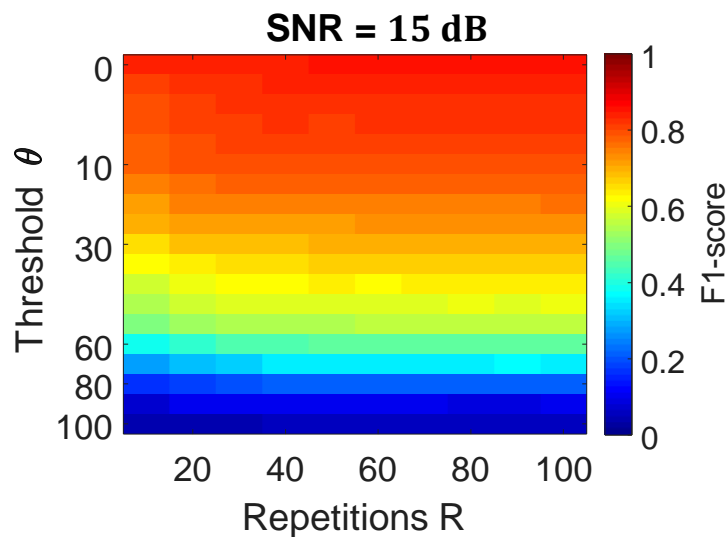- Songs with broad frequency bandwidth and high amplitude are more noise robust

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Scenario:

- Three sound sources played simultaneously
- Sound source positions placed randomly with uniform distribution
- Evaluation of performance based on inner parameter settings
- F1-score as the evaluation metric
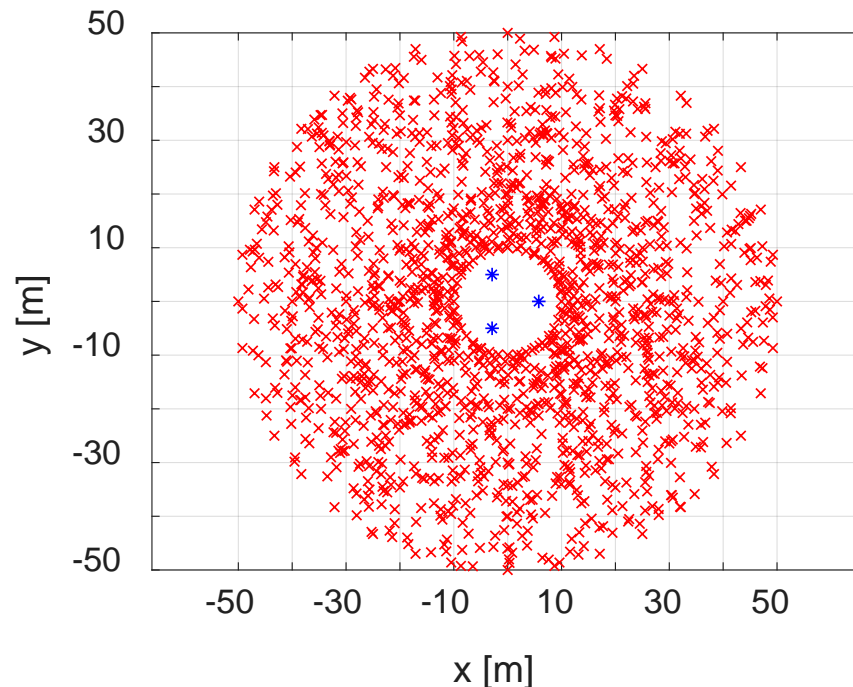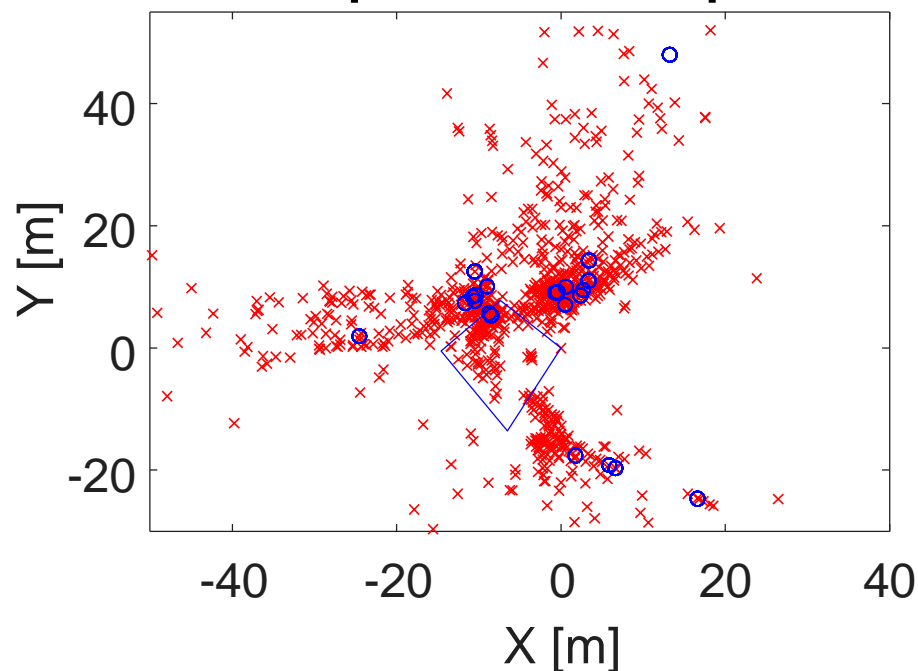
SNR = 15 dB

SNR = 0 dB

Highest score received for SNR = 15 dB:
- 0.8461

Highest score received for SNR = 0 dB:
- 0.7693

Experiment example

Summary:

- Explained the issues with 2D sound source localization.
- Evaluated the performance of our bird localization system in two parts.
- Gained understanding on the systems accuracy in different environment and parameter settings.

Future work

- Extending the system to perform 3D localization.
- Making the system perform in real time.
- Introducing VR visualization.
- Sound source classification with deep learning.

Thank you for your attention