IMPACT OF MICROPHONE ARRAY CONFIGURATIONS ON ROBUST INDIRECT 3D ACOUSTIC SOURCE LOCALIZATION

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# Acoustic Source Localization

m_i
m_j

1. Record acoustic signals using a microphone array
2. Calculate time difference of arrivals (TDOA)
3. Calculate the position using geometric formulae (optimization)

Locating The Source In 3D

Using a microphone array, we calculate Time Difference of Arrivals (TDOA) before we can estimate the acoustic source location
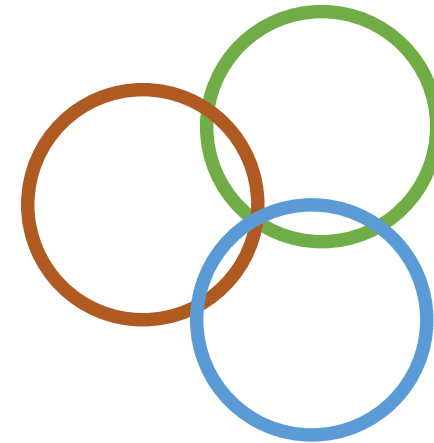
Steered Response Power (SRP)

Probability of the sound source being in this location
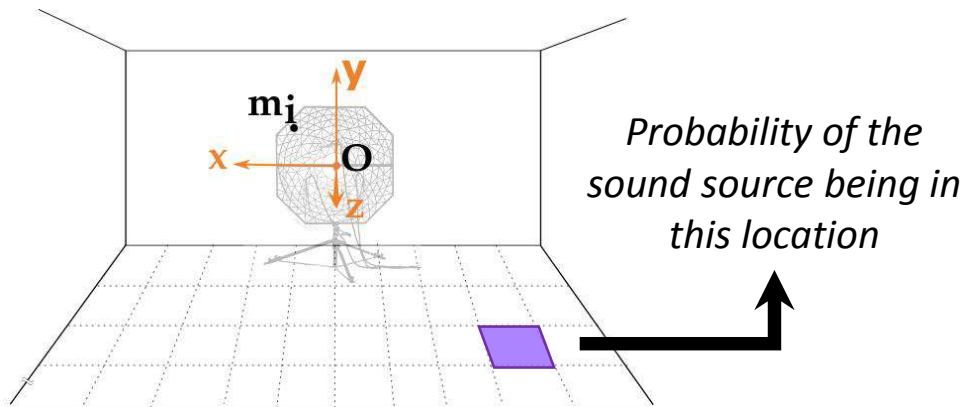
Most likely position amongst a grid of candidate locations
- ✔ Accurate
- ✘ Slow

Multilateration

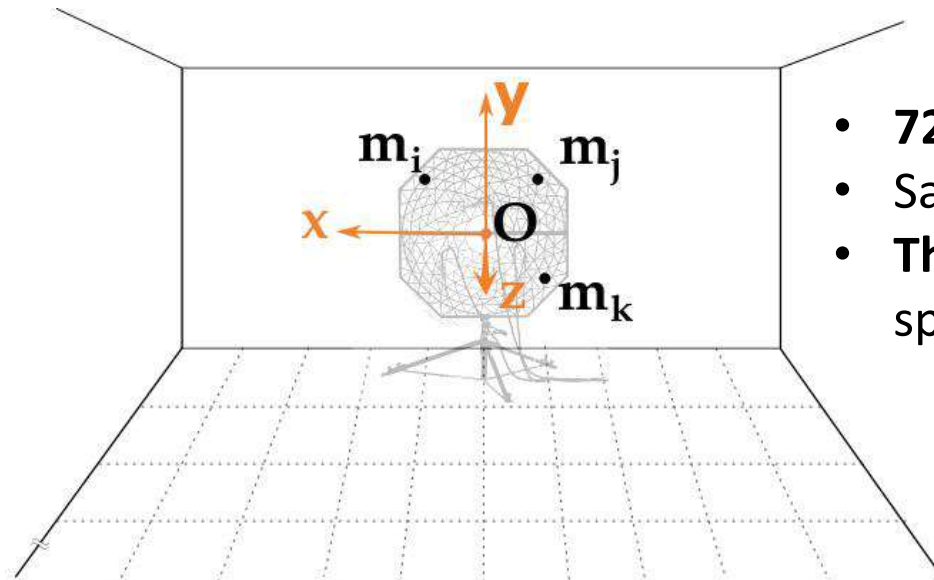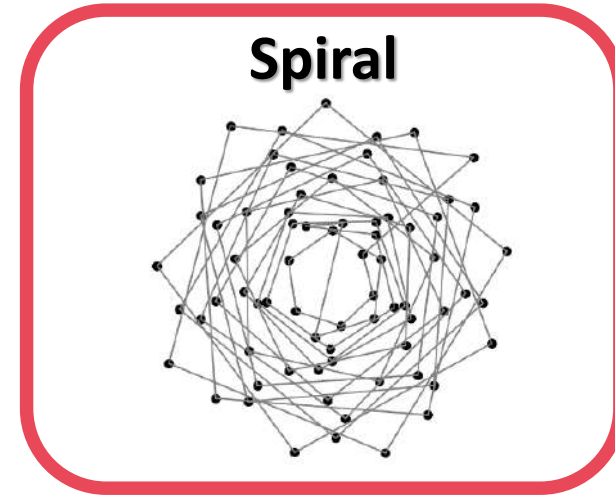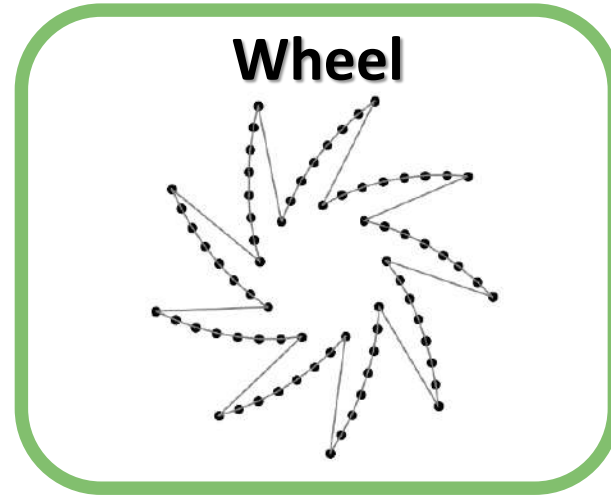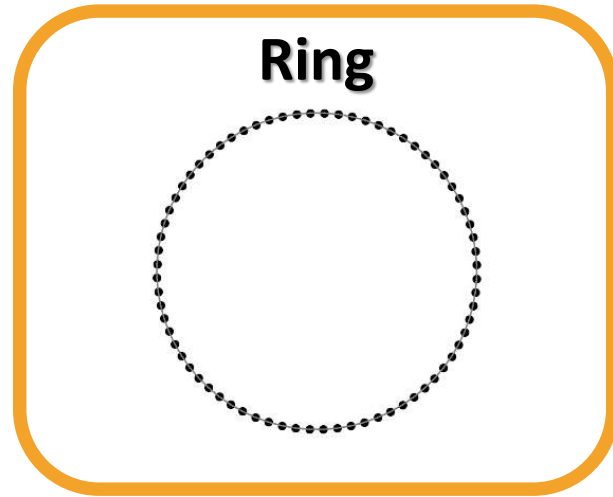Infer the source position via least squares optimization
- ✔ Fast
- ✘ Non-convex function, local minima

QUESTION #1:
Can localization be accurate and fast at the same time?

Microphone Arrays For Acoustic Source Localization

Ring

Wheel

Spiral
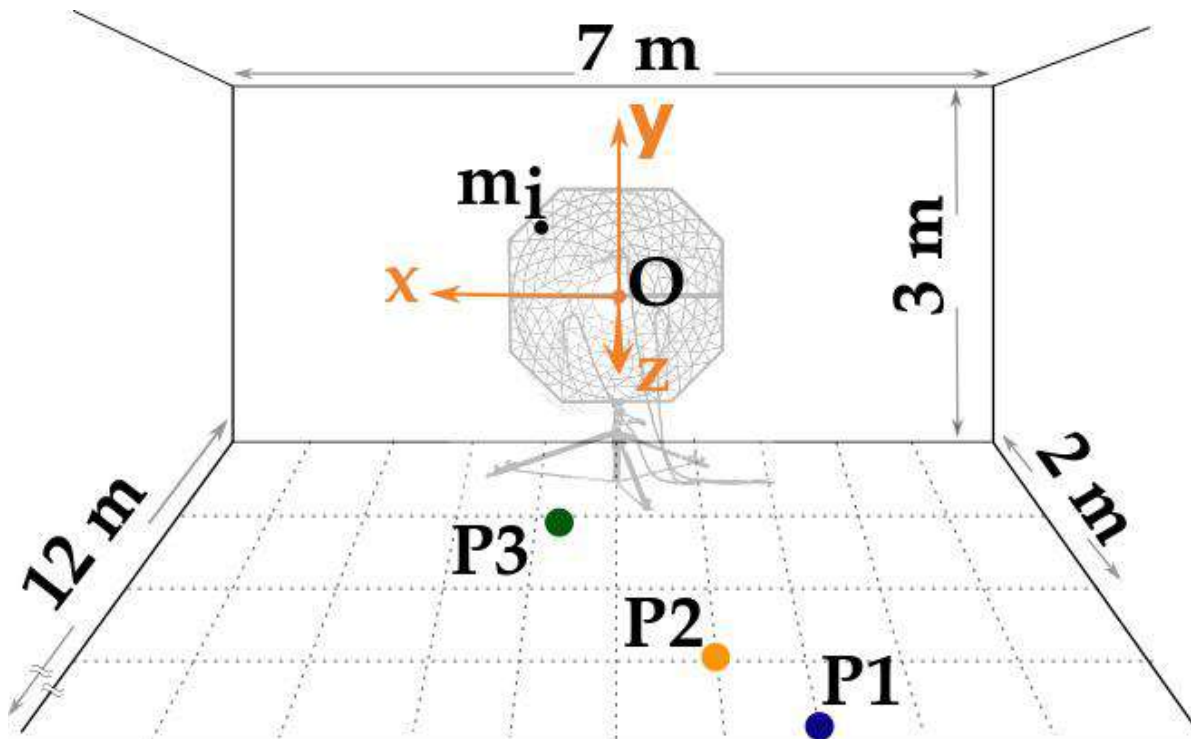
- **72** microphones
- Sampled at **192 kHz**
- **Three configurations** spanning the same area

QUESTION #2:
How does the microphone configuration affect localization accuracy?
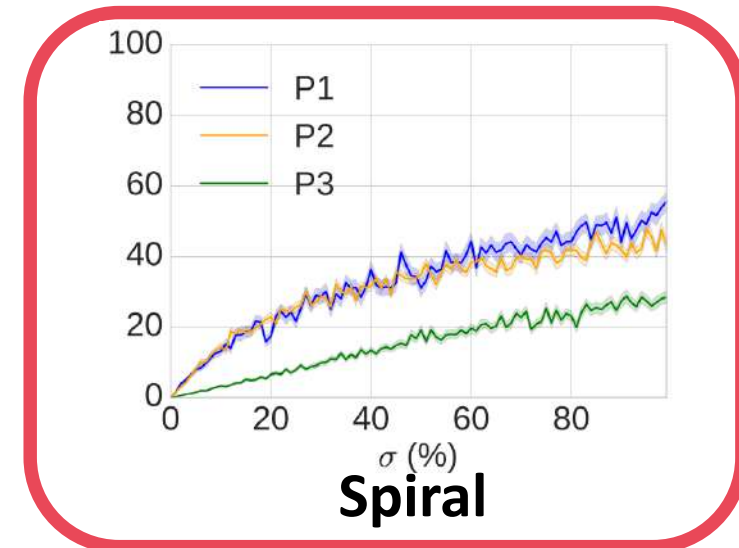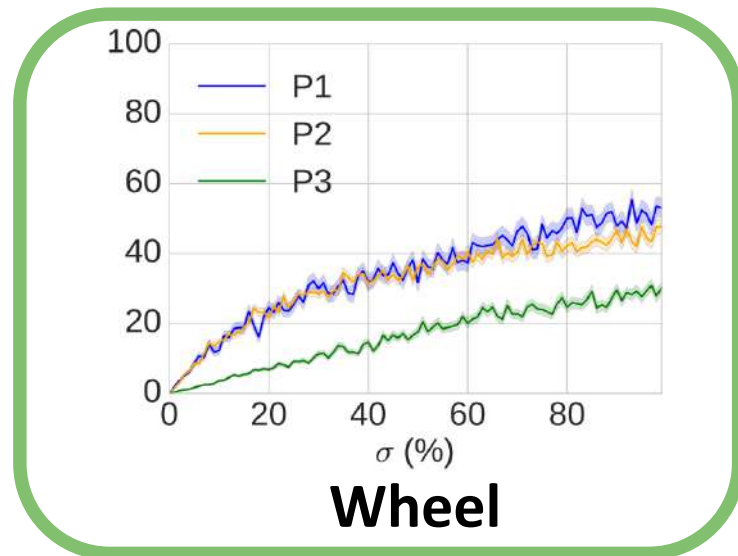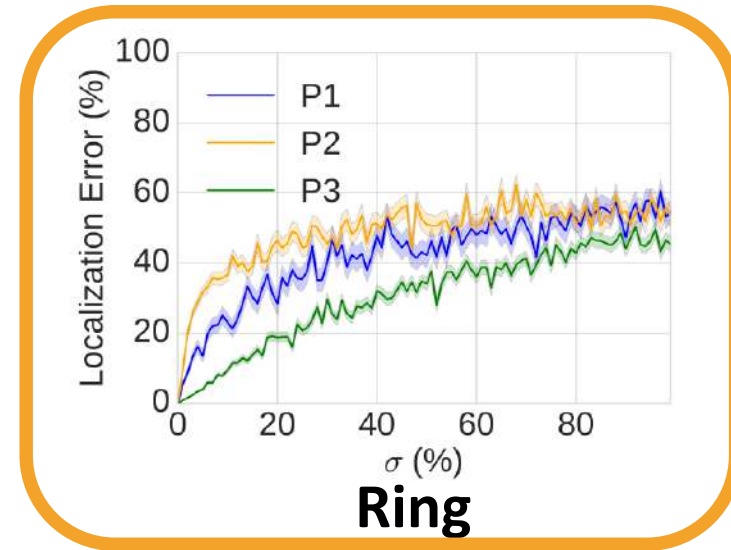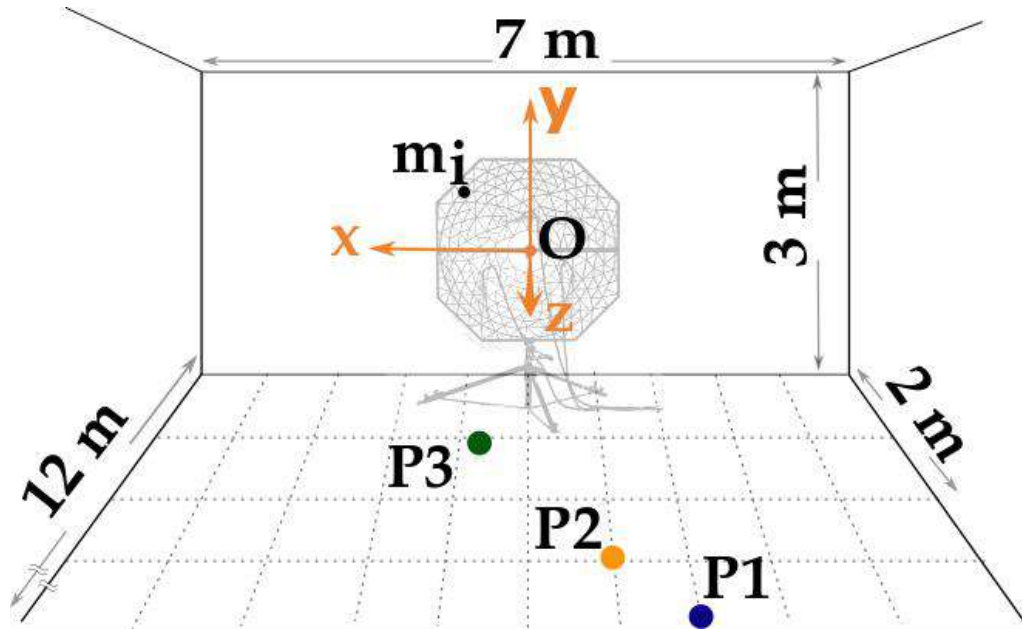
Simulated Source Locations

Noise added to Time Difference of Arrivals (TDOA)

$$\eta \sim \mathcal{N}\left(0, \frac{\sigma}{100}\frac{\|\mathbf{s}-\mathbf{O}\|}{c}\right)$$
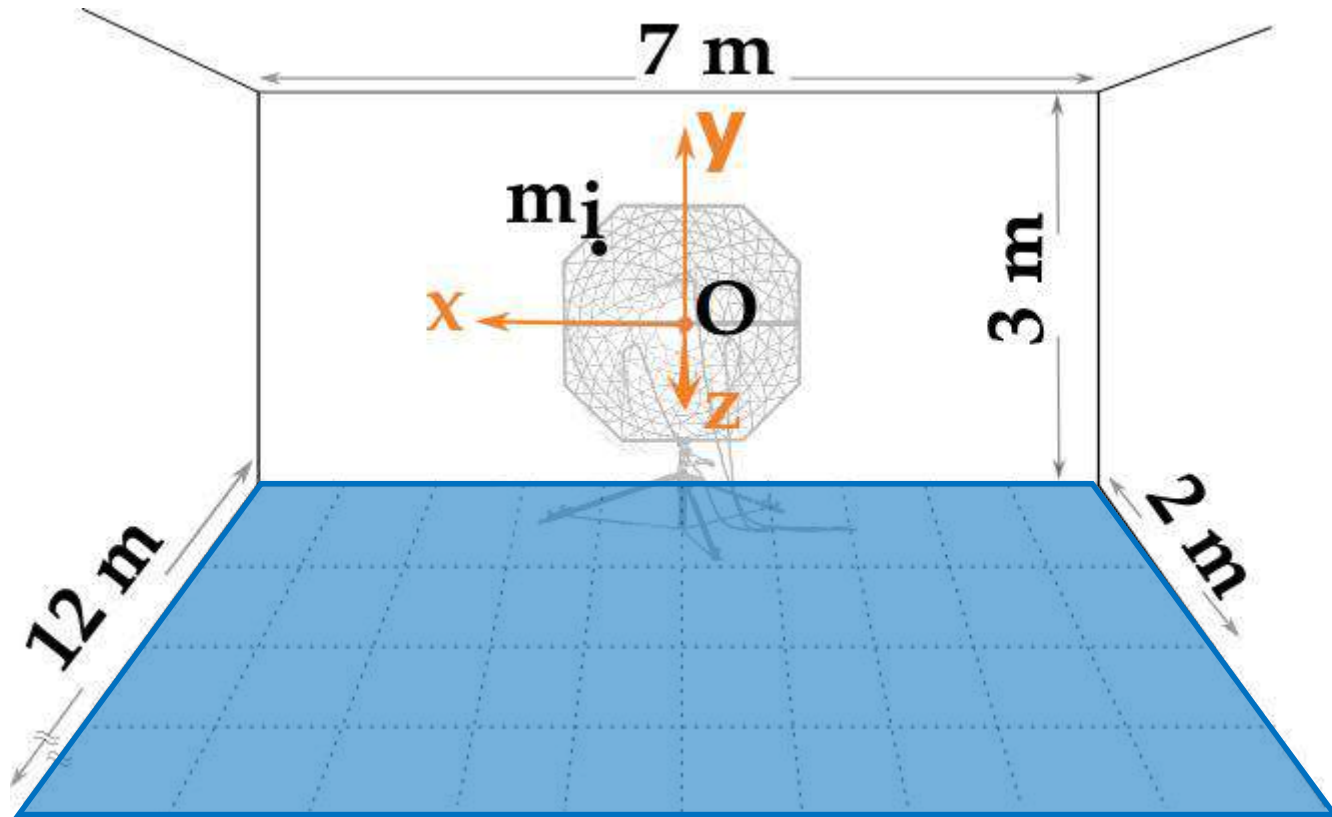
Localization Relative Error

$$\text{error}(\%) = \frac{\|\mathbf{s}-\tilde{\mathbf{s}}\|}{\|\mathbf{s}-\mathbf{O}\|} * 100$$

Wheel and Spiral Configurations Are More Robust

Simulated Source Locations
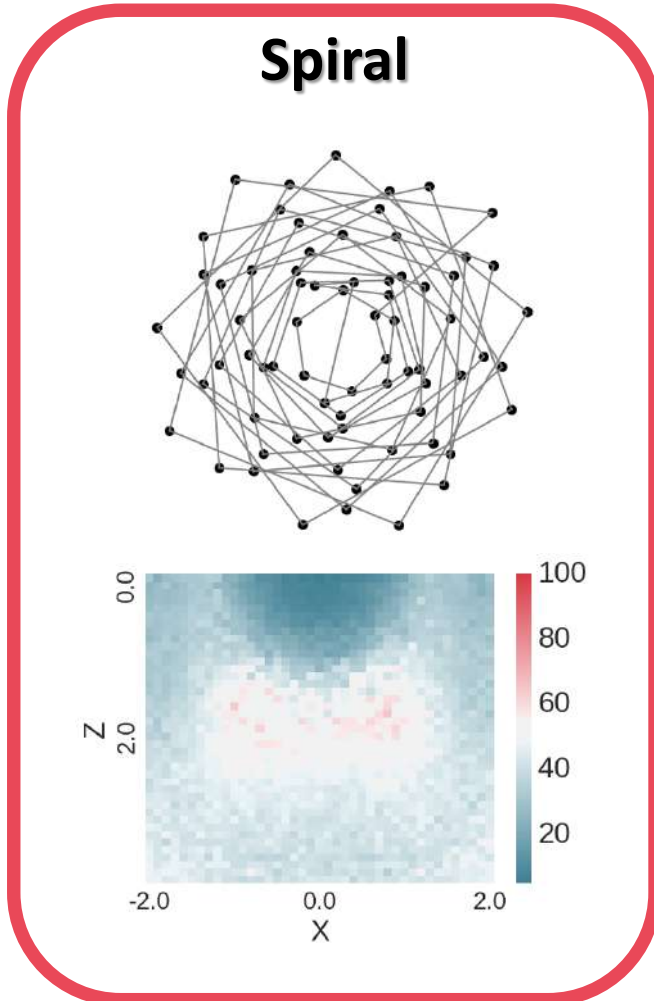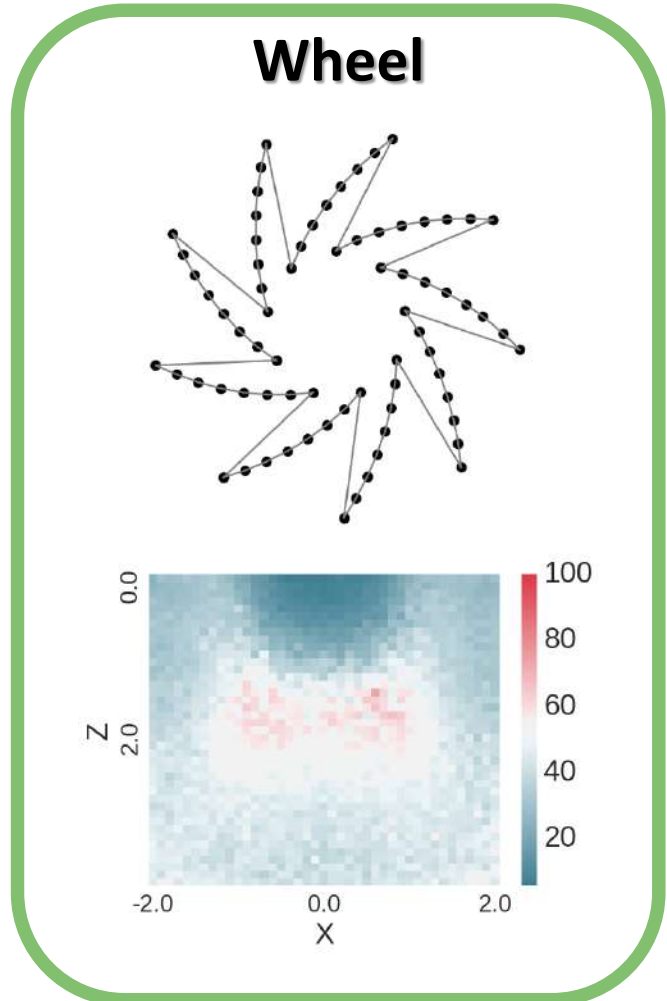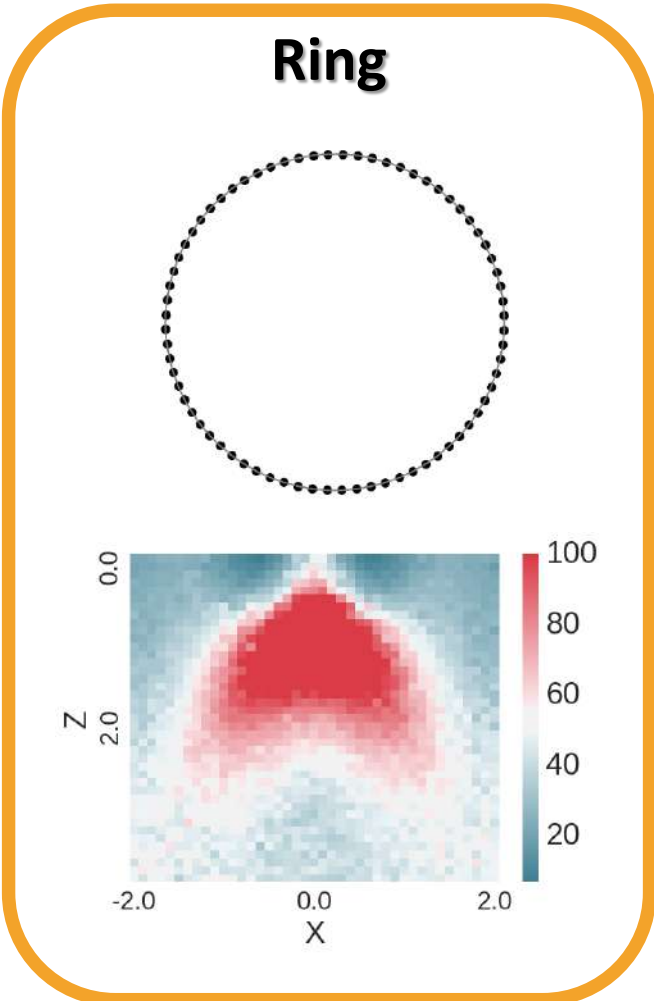

Noise added to Time Difference of Arrivals (TDOA)

$$\eta \sim \mathcal{N}\left(0, \frac{\sigma}{100}\frac{\|\mathbf{s}-\mathbf{O}\|}{c}\right)$$

Localization Relative Error

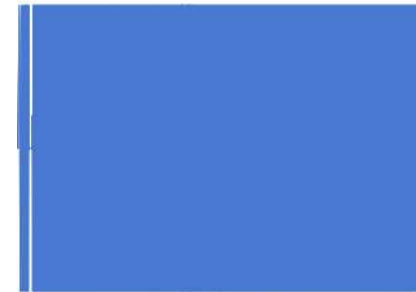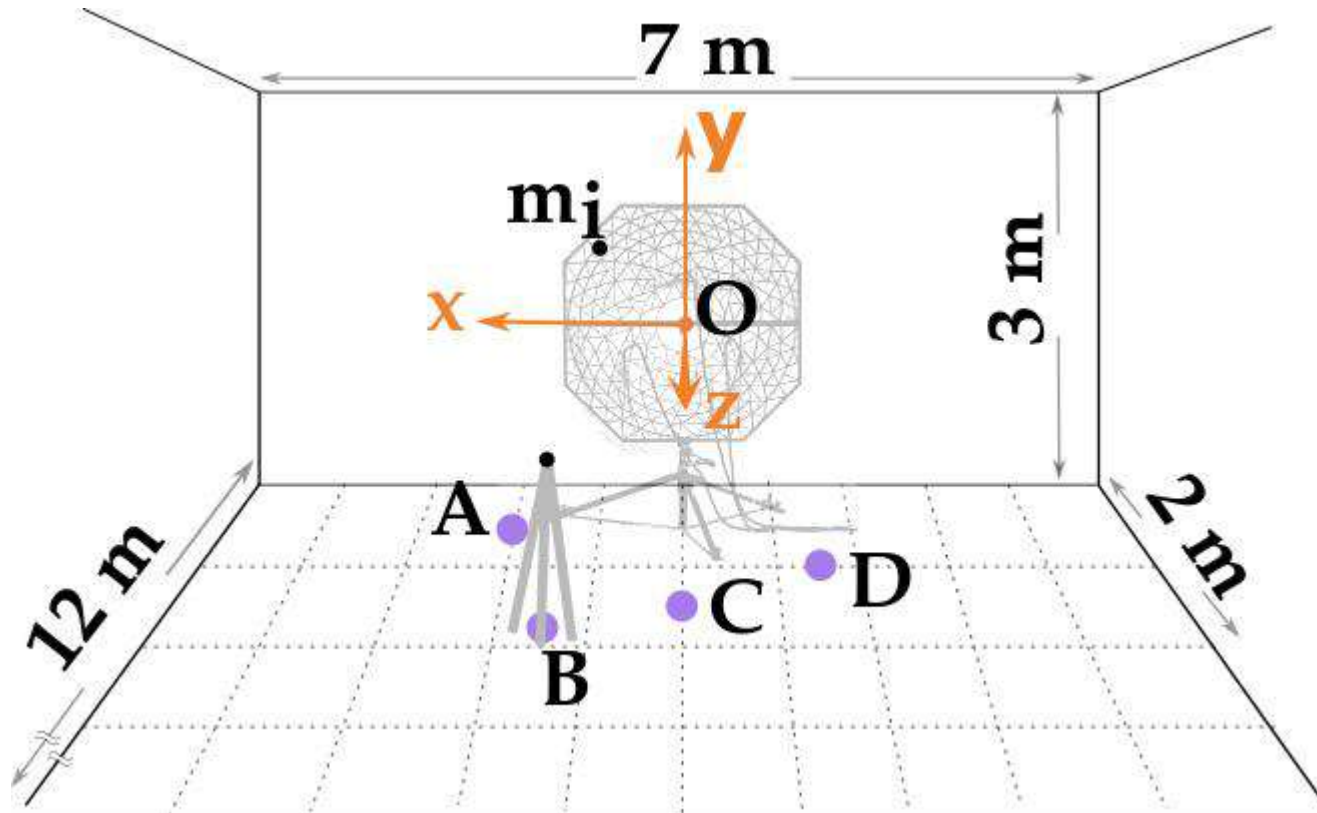$$\text{error}(\%) = \frac{\|\mathbf{s}-\tilde{\mathbf{s}}\|}{\|\mathbf{s}-\mathbf{O}\|} * 100$$

Higher Errors Observed With Ring Configuration

100% noise for a 2m by 2m room with 3 different configurations spanning the same area
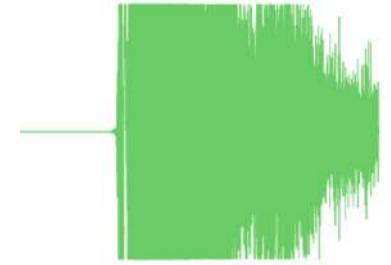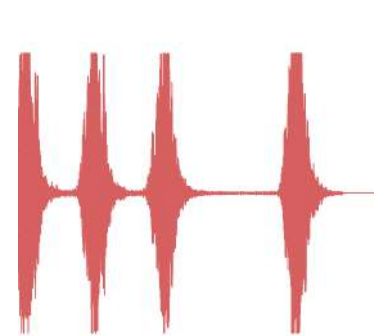
Using Real Data

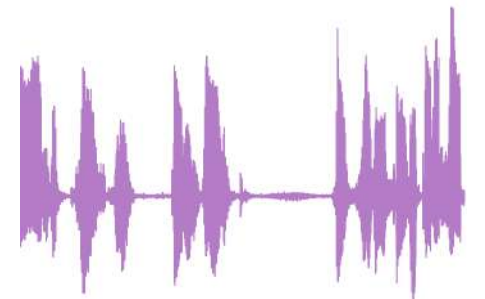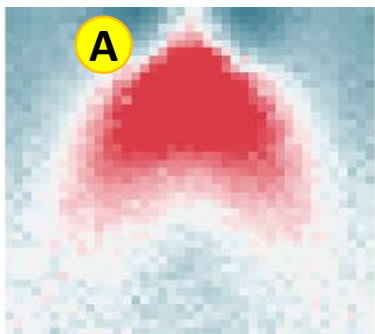We tested both Multilateration and Steered Response Power (SRP)
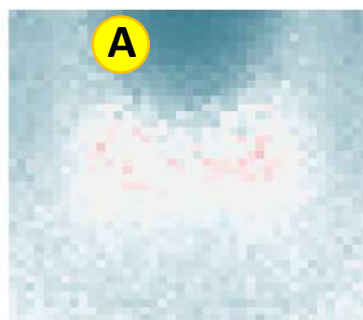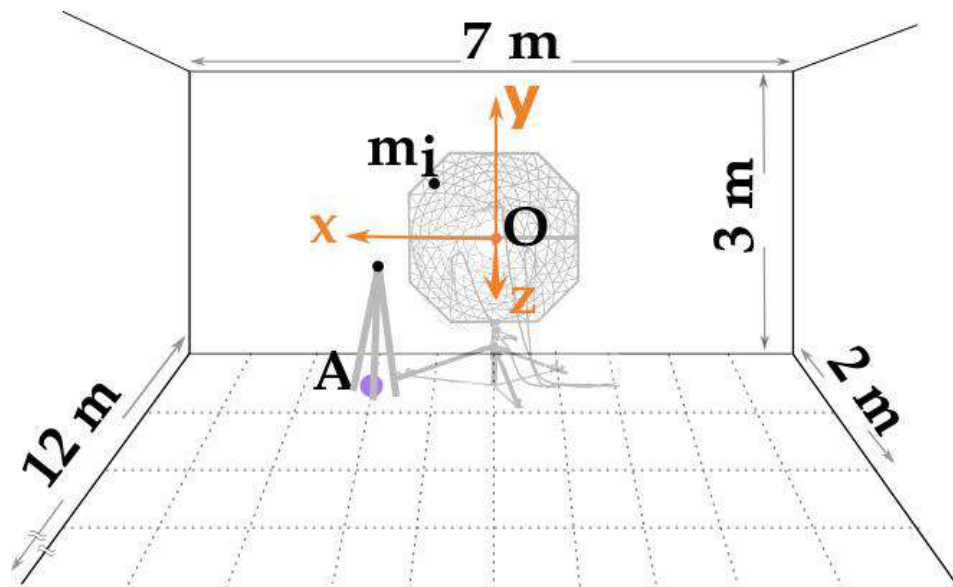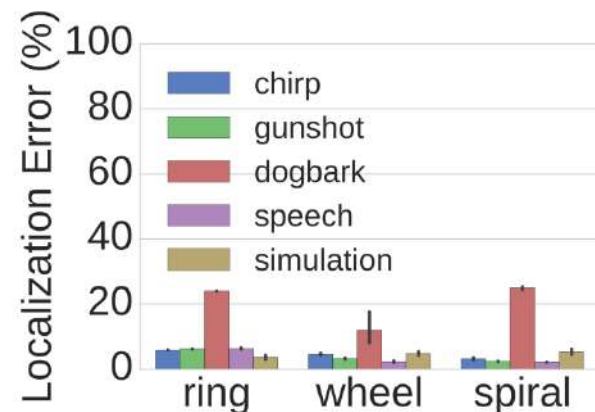

chirp

gunshot

dogbark

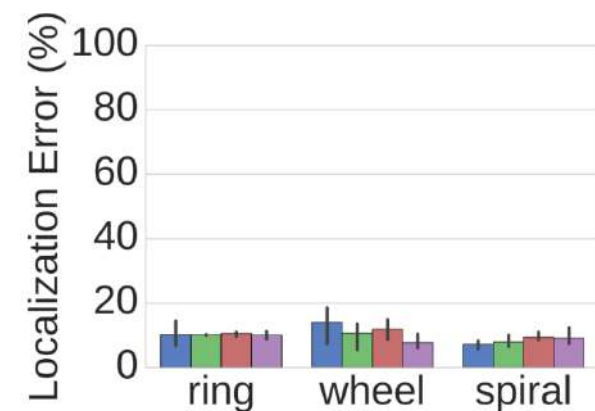speech

Short Range Localization
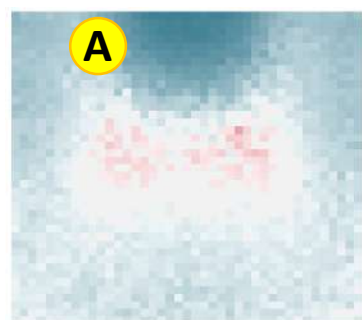
Ring

Wheel

Spiral

A: (2.0,-0.32,0.5)

Multilateration

SRP

Mid Range Localization

Ring

Wheel

Spiral

B: (1.5,-0.32,2.0)

Multilateration

SRP
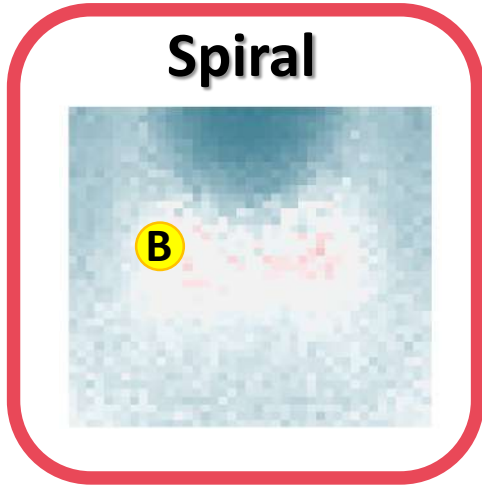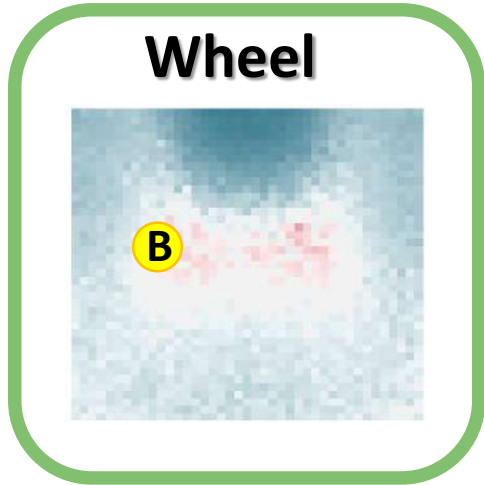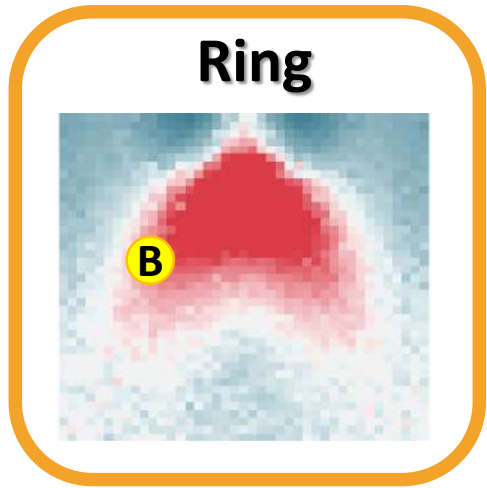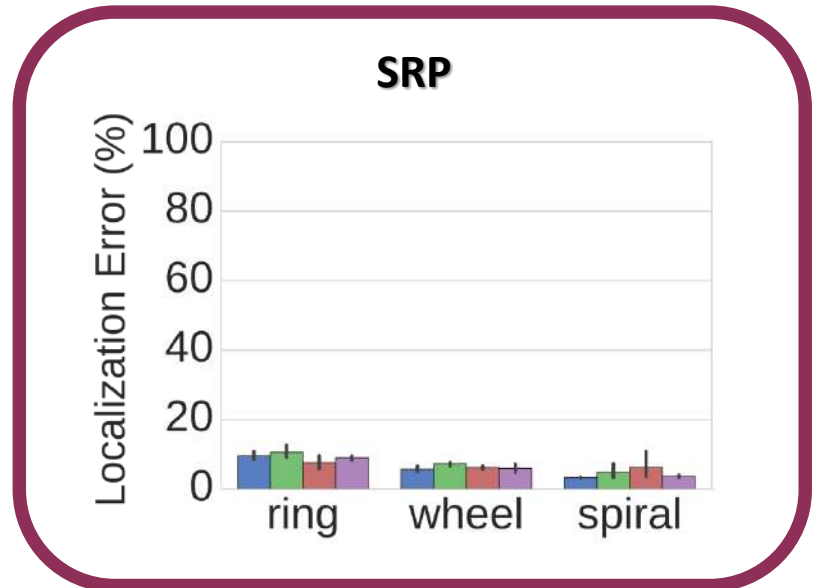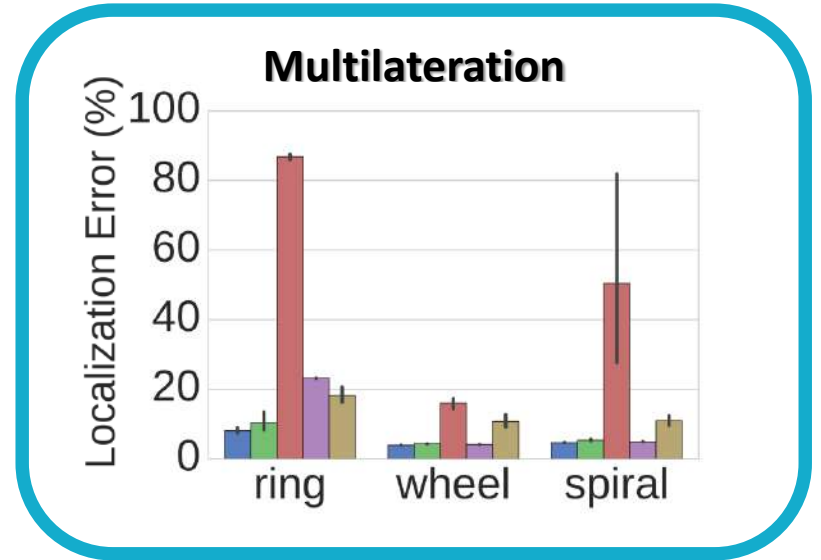
Facing The Microphone Array

Ring

Wheel

Spiral

C: (0.0,-0.32,1.5)

Multilateration

SRP
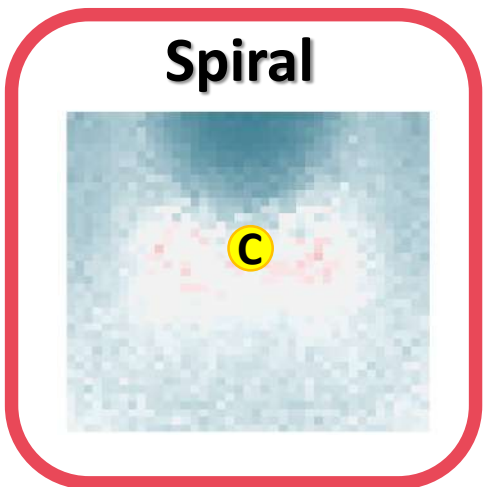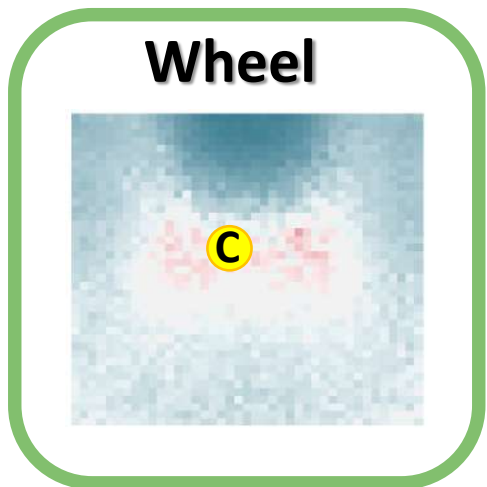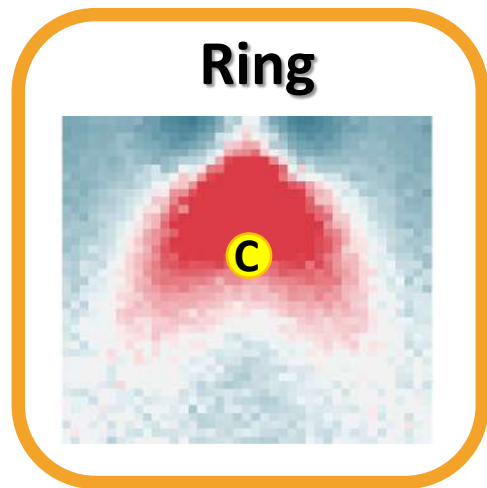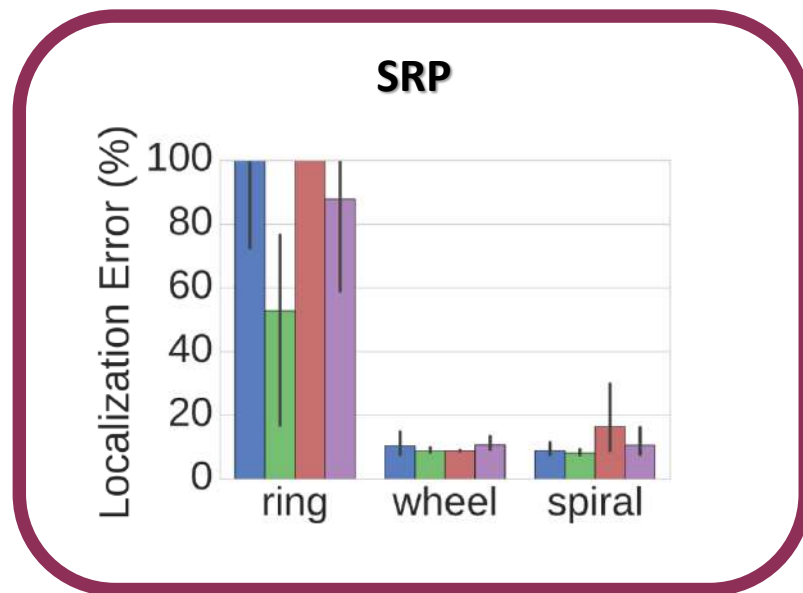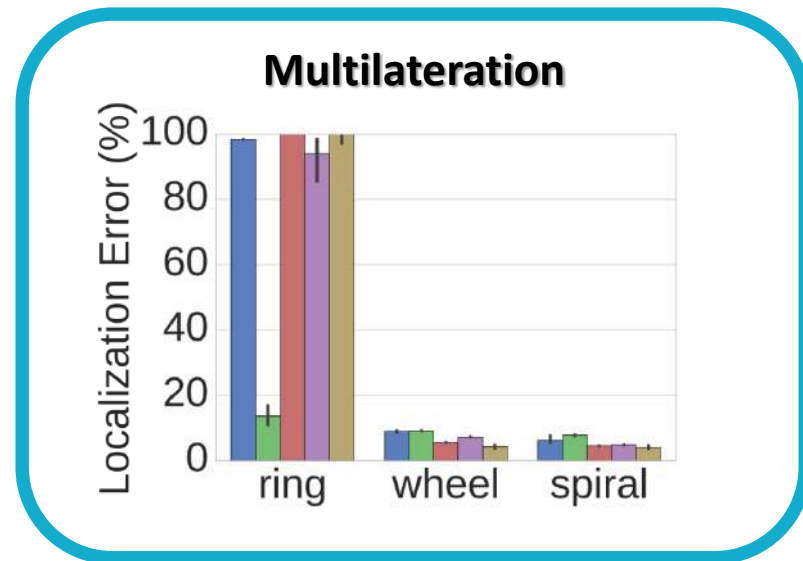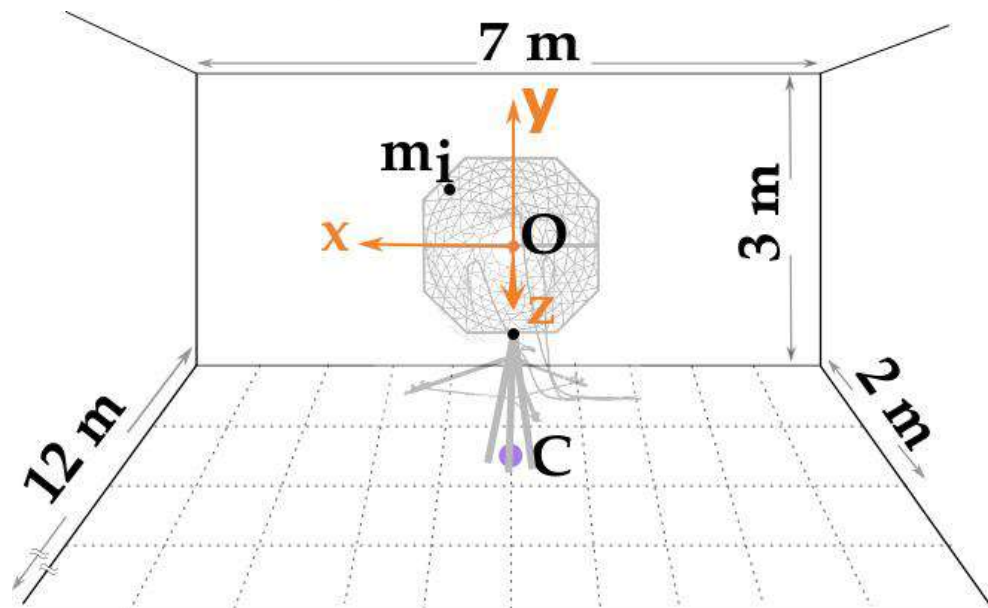
Mid Range Localization

Ring

Wheel

Spiral

D
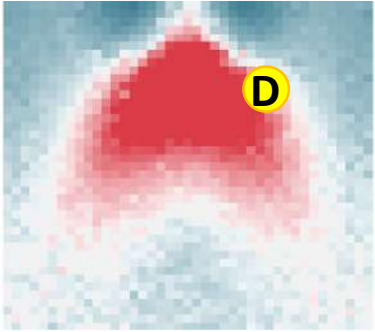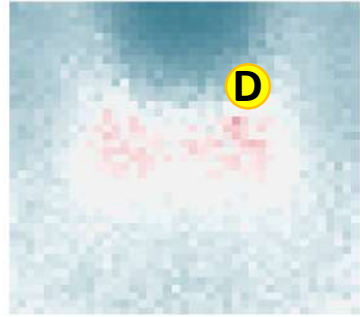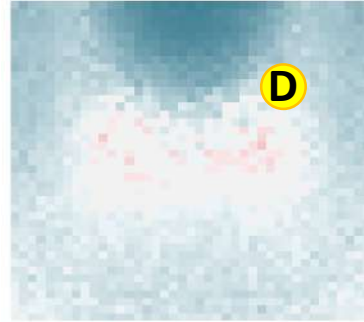
D: (-1.5,-0.32,1.0)
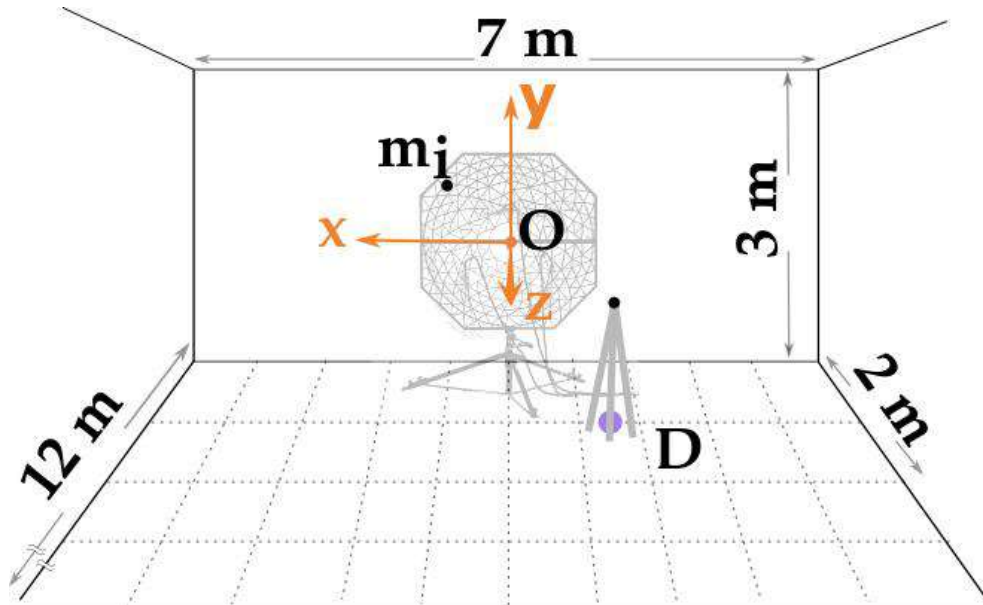
Multilateration
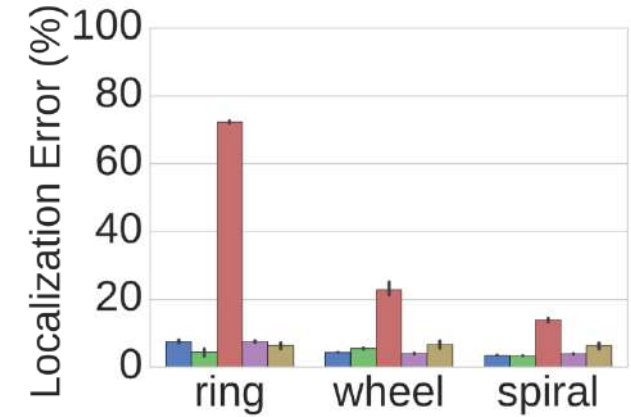
SRP
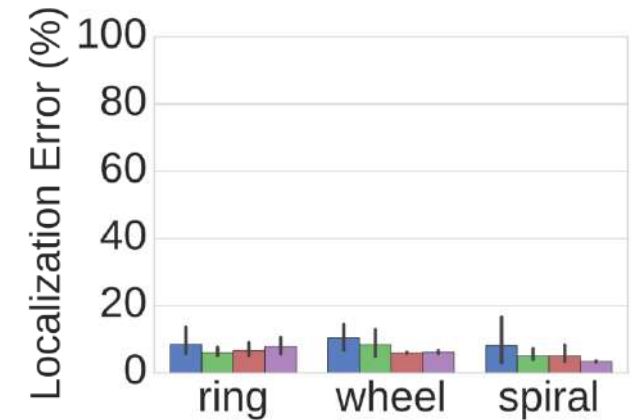
What Happened To The Speed?

Using a microphone array, we calculate Time Difference of Arrivals (TDOA) before we can estimate the acoustic source location
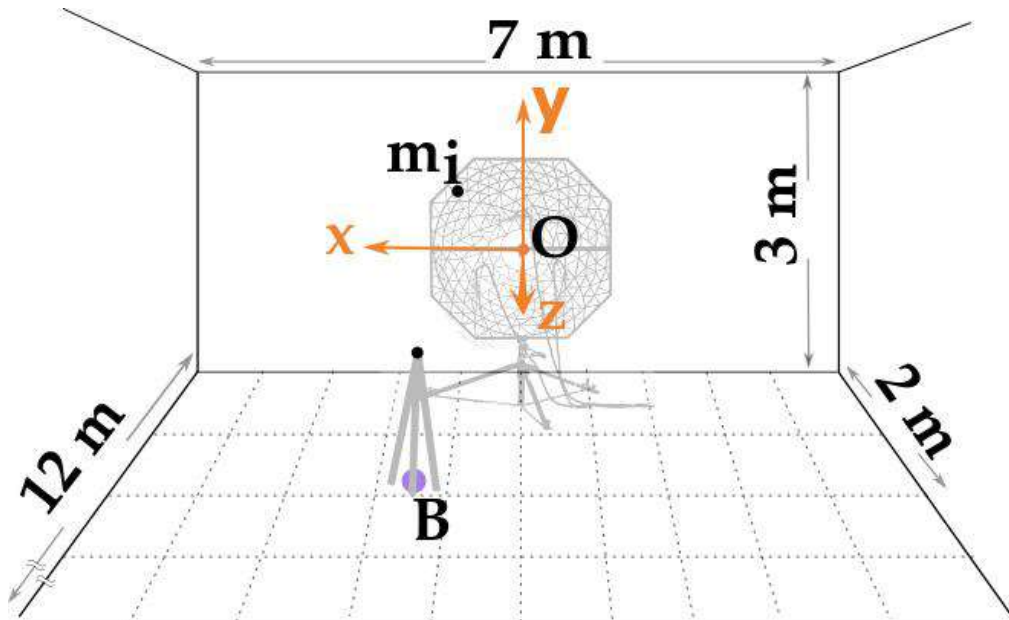
Steered Response Power (SRP)

Probability of the sound source being in this location
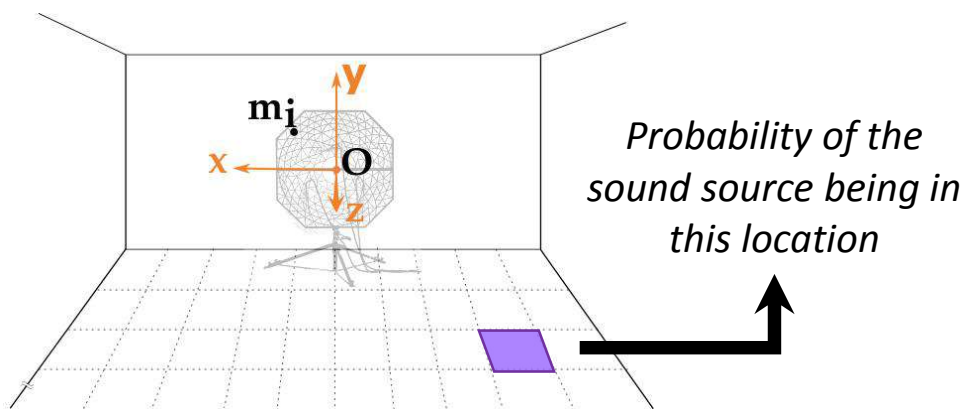
Most likely position amongst a grid of candidate locations
✔Accurate
✘ Slow

Multilateration
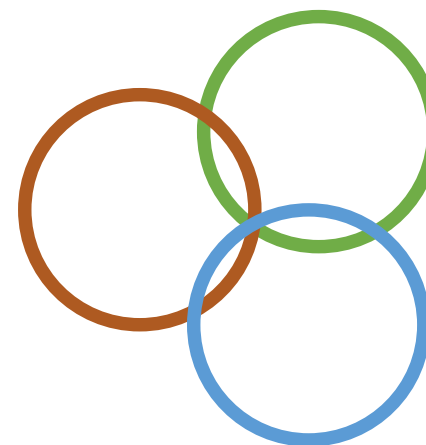
Infer the source position via least squares optimization
✔ Fast
✘ Non-convex function, local minima

How Many Microphone Pairs To Use?
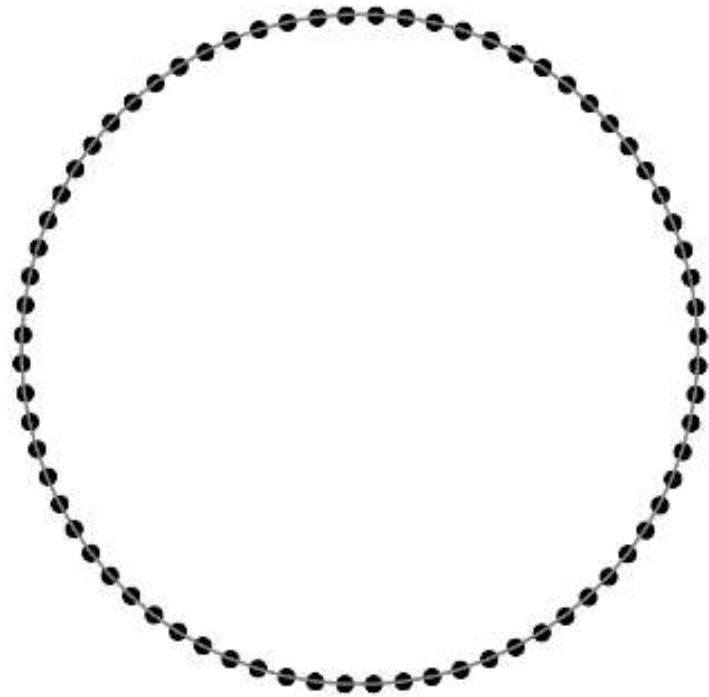
72 microphones

Array 16 Microphones

120 Pairs

Array 32 Microphones

496 Pairs

Array 72 Microphones

2556 Pairs

Using 2556 Microphone Pairs

Accuracy (%)

Signal	SRP	Multilateration
Chirp	14.7 (25.9)	12.1 (23.2)
Gunshot	11.0 (13.3)	6.4 (3.5)
Dogbark	16.0 (28.5)	48.5 (44.6)
Speech	13.2 (21.1)	12.9 (22.5)

Time (minutes)

Signal	SRP	Multilateration
Chirp	3 (0.2)	4.5 (0.03)
Gunshot	2.58 (0.2)	2.4 (0.02)
Dogbark	2.49 (0.1)	2.4 (0.02)
Speech	2.63 (0.1)	2.5 (0.02)

Using 100 Microphone Pairs

Accuracy (%)

Signal	SRP	Multilateration
Chirp	14.7 (25.9)	14.2 (25.9)
Gunshot	11.0 (13.3)	9.6 (12.8)
Dogbark	16.0 (28.5)	58.9 (38.8)
Speech	13.2 (21.1)	15.2 (23.5)

Time (minutes)

Signal	SRP	Multilateration
Chirp	3 (0.2)	0.5 (0.01)
Gunshot	2.58 (0.2)	0.4 (0.02)
Dogbark	2.49 (0.1)	0.4 (0.02)
Speech	2.63 (0.1)	0.4 (0.02)

Conclusions

QUESTION #1:
Can localization be accurate and fast at the same time?

Yes it can! Direct optimization yields errors similar to the Steered Response Power (SRP) method with <u>6 times less computation</u>

QUESTION #2:
How does the microphone configuration affects the localization accuracy?

Circular arrays are the <u>least desirable</u> configuration