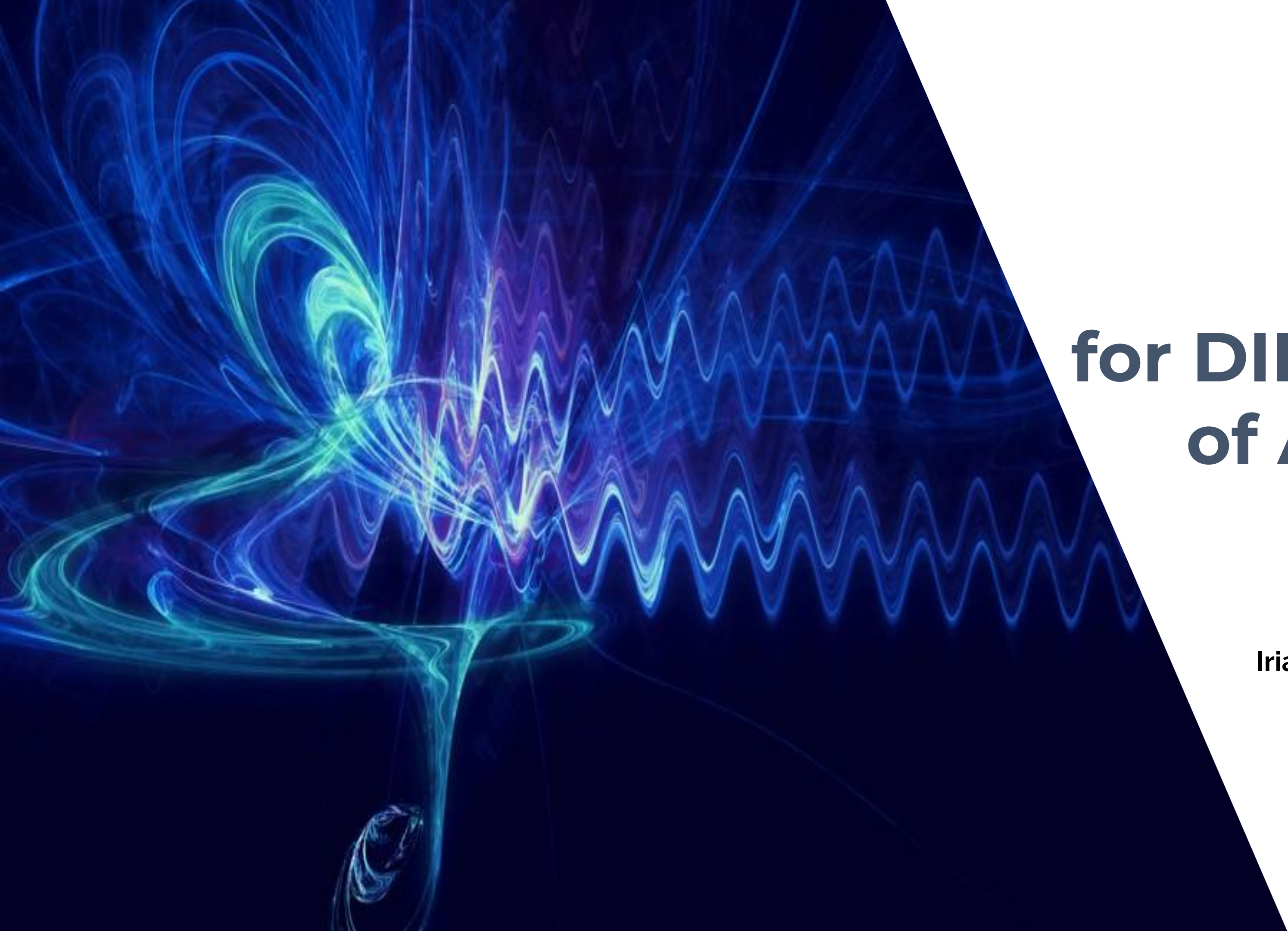

COM-500: Project

MUSIC for DIRECTION of ARRIVAL

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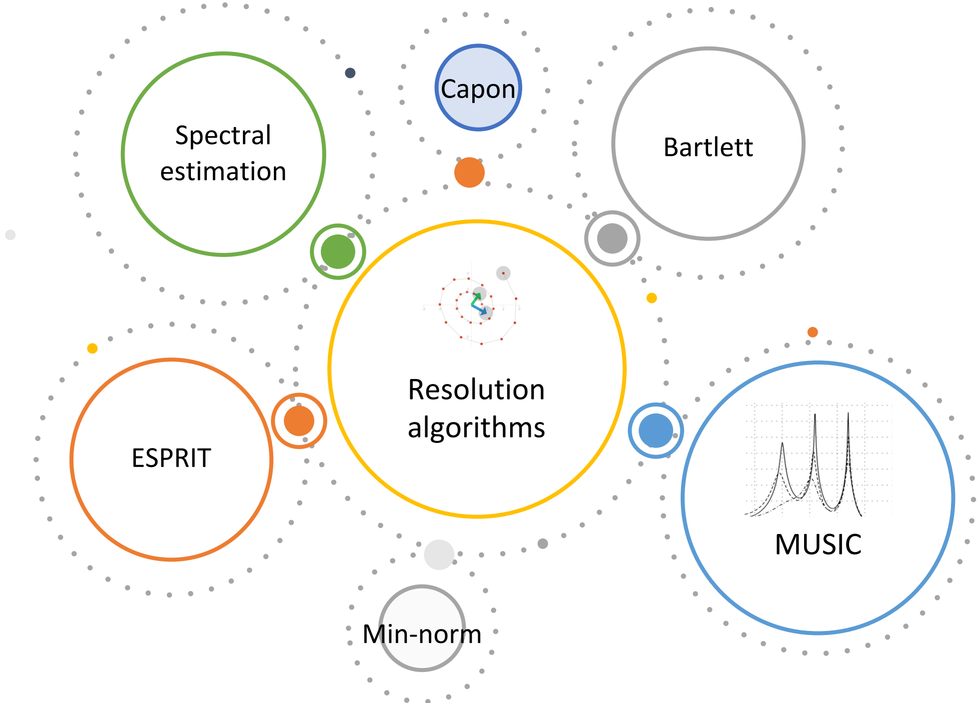
INTRODUCTION

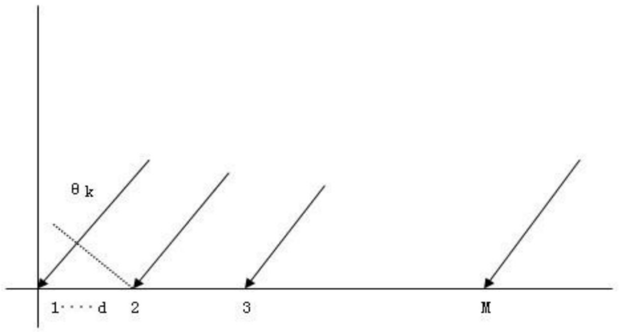
Spatial spectrum estimation can be also called as Direction of arrival (DOA) estimation.

Advantages of MUSIC:

1. The ability to simultaneously multiple signals.
2. High precision measurement
3. High resolution for antenna beam signals
4. Applicable to short data circumstances
5. It can achieve real-time processing after using high-speed



MUSIC algorithm for DOA



Spaced linear array and far field

Conditions for the mathematical model of DOA:

1. The signal sources (D) are narrow bands and the same center frequency.
2. The array is a spaced linear array (M>D). It is isotropic in each direction.
3. The spacing is d, and interval $\leq \lambda_{min}/2$
4. Each receiver in the far field source(plane wave)
5. Both array elements and test signals are uncorrelated
6. Each receiving brunch has the same characteristic

Array receiver used in order to distinguish multiple signals.

$$x_m(t) = \sum_{k=1}^{D} s_k(t) \exp\left[-j(m-1)\frac{2\pi \, \mathrm{d} \sin\theta_k}{\lambda}\right] + n_m(t)$$

$$a_m(\theta_k) = \exp[-j(m-1)\frac{2\pi \, \mathrm{d} \sin\theta_k}{\lambda}]$$

$$x_m(t) = \sum_{k=1}^{D} a_m(\theta_k) s_k(t) + n_m(t)$$

$$X=[x_1(t),x_2(t),\ldots,x_M(t)]^T,$$

$$S=[S_1(t),S_2(t),\ldots,S_D(t)]^T,$$

$$A=[a(\theta_1),a(\theta_2),\ldots,a(\theta_D)]^T$$

$$=\begin{bmatrix} 1 & 1 & \cdots & 1 \\ e^{-j\varphi_1} & e^{-j\varphi_2} & \cdots & e^{-j\varphi_D} \\ \cdots & \cdots & \cdots & \cdots \\ e^{-j(M-1)\varphi_1} & e^{-j(M-1)\varphi_2} & \cdots & e^{-j(M-1)\varphi_D} \end{bmatrix}$$

$$\text{with } \varphi_k=\frac{2\pi d}{\lambda}\sin\theta_k,$$

$$X=AS+N$$

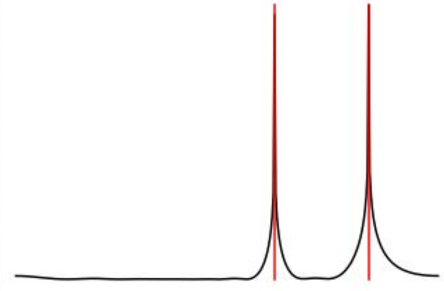
DOA on Generated Data

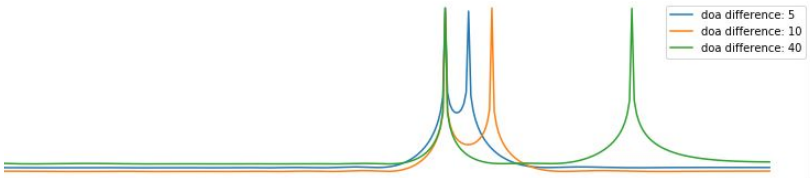
Implementations on generated Data with following variations:

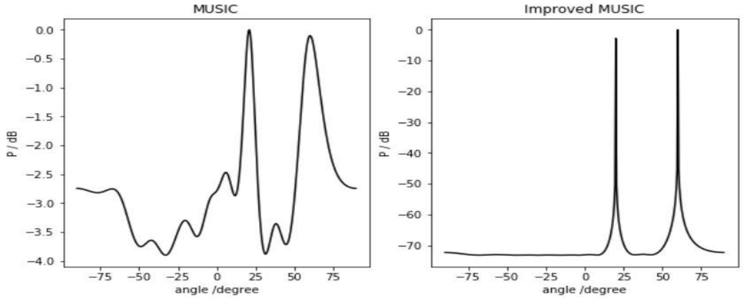
a) Power of noise
b) number of microphones in an array
c) distance between mics
d) number of snapshots
e) angle difference of DOA
f) correlated signals (use improved MUSIC)

DEMO1: DOA_part1(generated-data).ipynb

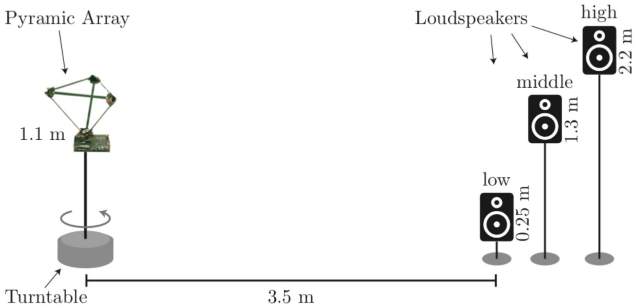
Figure 1 : MUSIC result for two sources
Figure 2 : MUSIC result, different angle difference
Figure 3 : correlated signal and improved MUSIC



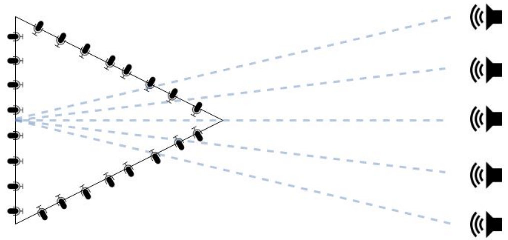




DOA on Real Data



Experiment Setup



Implementations on real data:

1) Single Source
   a) Single edge ✓
   b) Triangle ✓
2) Multiple Source
   a) Correlated and uncorrelated (Single edge) ✓✗
   b) Correlated and uncorrelated (Triangle) ✓✗

31) Simulation with pyroomacoustics library:
   a) Developed at EPFL
   b) Improved results
   c) Correlated ✓
   d) Uncorrelated ✓

DEMO2: DOA_part2(real-data).ipynb

CONCLUSION

1) Music algorithm works well for Direction of Arrival, given certain conditions and assumptions.
2) Music limitations:
    a) It must meet all the assumptions described above.
    b) It does not perform good with correlated sources.
3) Improved Music:
    a) It works well for correlated sources.
    b) It helps calibrate possible errors.
    c) Saves Computation
4) Dealing with Real Data:
    a) Music for DOA works well for generated data (single and multiple sources)
    b) Frequency variability of real data, it may not be narrow frequency.
    c) Difficulties to identify multiple sources with real data.
5) Possible Improvements
    a) STFT
    b) Consider 3D mics arrangement

THANK YOU!

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