DSP Project

Assignment: Direction of arrival (DoA) estimation

In this assignment, the narrowband and wideband direction of arrival (DOA) estimation algorithms have to be implemented and evaluated.

Scenario 1: Narrow-band DoA estimation

Consider the array processing scenario in a two dimension space which is now depicted in Fig.1. The sensors are located as a $J = 4$ elements uniform linear array (ULA) on the x-axis with a mutual spacing of $dx = 0.25$cm with the origin in the center of the array. The position of the i'th sensor is represented by the row vector $\underline{p}_i = [p_x, p_y]$.

A desired narrowband source signal with center frequency $f_c = 680$Hz is assumed to arrive at the sensor array from the far field under an angle of θ_{s1}. A second interfering source s_2 also has a center frequency of f_c but arrives from another angle θ_{s2}. We know for the desired and interfering sources that $(|\theta_{s1}| < |\theta_{s2}| < \pi/2)$. The medium in which the sound waves are traveling is air which results in a speed of sound of $c = 340$m/s.

The observations are contaminated by spatially and temporally white Gaussian noise. We assume that the noise variances are the same and all signals are uncorrelated with respect to each other. The observations of a simulation of DOA estimation scenario are available in the file *Observation_nb.mat*. The sample rate is $16kHz$, which is also specified in the mat file.

One well known high resolution spectral estimation technique is the MUSIC algorithm. The MUSIC algorithm applies the steering vector for each angle of arrival to a projection matrix that is based on the noise subspace. The resulting pseudo spectrum contains very sharp peaks that represent the angles of arrival.

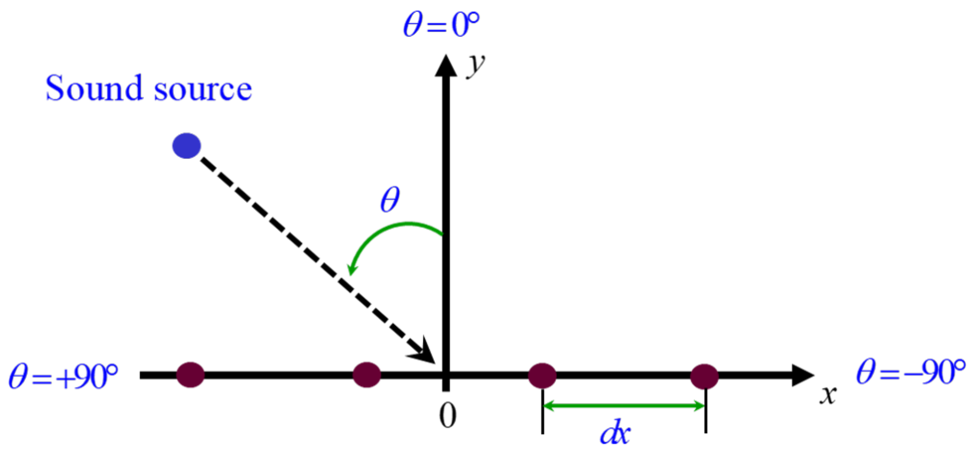

Figure 1: Array configuration

a) Given an example of narrow-band signal, plot the wave of time-domain and magnitude of frequency-domain.

b) Complete the code and apply the MUSIC algorithm to the observations. Plot the spatial spectrum for the range of $-\frac{\pi}{2} < \theta < \frac{\pi}{2}$ with a resolution of at least $1°$.

c) Try to counteract the effect of interfering source by compensating the phase shift in each sensor when we know the direction of arrival of the undesired source and then listen to the output after compensating.

Scenario 2: Wide-band DoA estimation

In this scenario, the two wide-band male and female speech sources under noisy environment impinge on four elements uniform linear array in different angles. The uniform linear array configuration is the same as scenario 1. And the observations are available in the file *Observation_wb.mat*. The sample rate is $16kHz$, which is also specified in the mat file. While the narrowband formulation of the MUSIC algorithm is straightforward to follow, it does not work well for nonstationary speech signal. The short-time Fourier transform (STFT) is a general way to processing non-stationary speech signals.

a) Listen to the sounds of the first sensor using *soundsc* command. Plot the wave in time domain with x-axis represented by t (s) and plot the magnitude of the frequency response and represent x-axis in $frequency$ (Hz).

b) Perform short-time Fourier analysis on the observations. Divide the observations into different segments, and each segment is regarded as a stationary signal. Then do discrete Fourier analysis for each segment. Treat the same frequency band in all divisions as narrow-band and perform narrow-band MUSIC algorithm in each frequency band.

c) Try to counteract the effect of interfering source by compensating the phase shift in each sensor when we know the direction of arrival of the undesired source and then listen to the output after compensating.

References

Direction of Arrival (DoA): https://en.wikipedia.org/wiki/Direction_of_arrival
Sensor array: https://en.wikipedia.org/wiki/Sensor_array
Array processing: https://en.wikipedia.org/wiki/Array_processing
MUSIC algorithm: https://en.wikipedia.org/wiki/MUSIC_(algorithm)
Short-time Fourier transform (STFT): https://en.wikipedia.org/wiki/Short-time_Fourier_transform