University of Ottawa

Assignment 3 - source separation

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Mathematical Formulations

Wiener Filter

To compute optimal multichannel Wiener filter, P matrix and R matrix need to be computed.

P Matrix

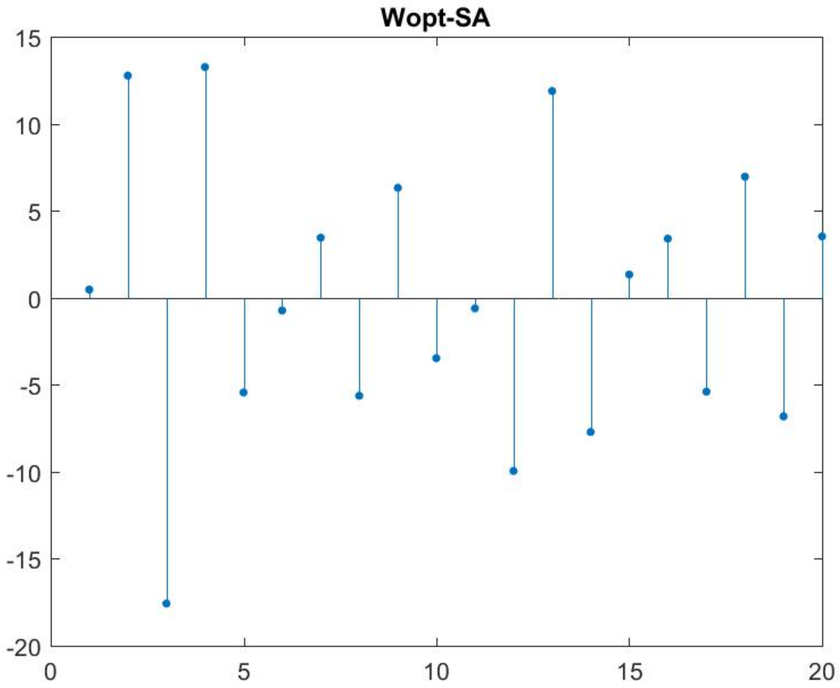
$$P = [\phi_{x1d}(0) \; \dots \; \phi_{x1d}(-N+1), \;\; \phi_{x2d}(0) \; \dots \; \phi_{x2d}(-N+1)]^T$$

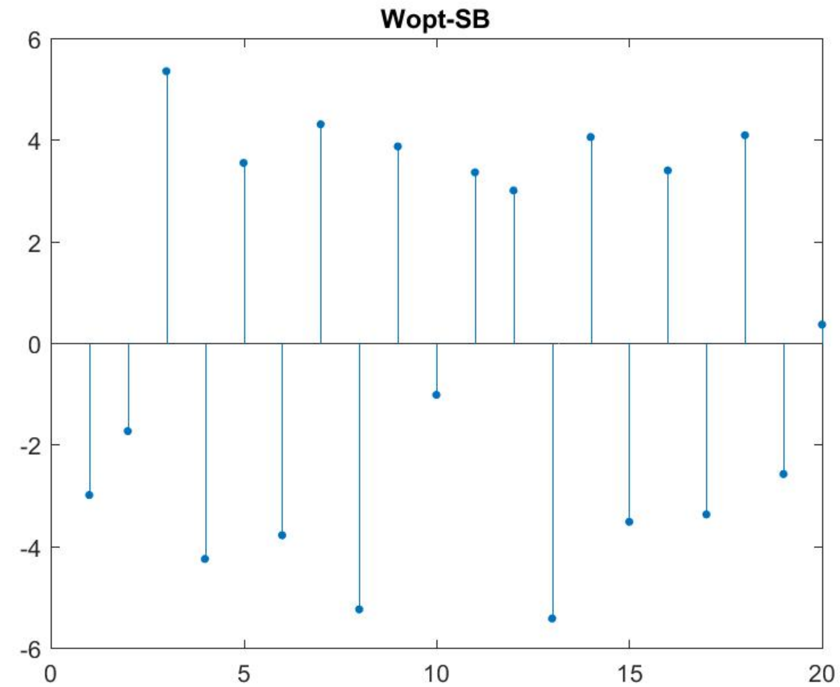
R Matrix

$$R = \begin{pmatrix} \begin{pmatrix} \phi_{x1x1}(0) & : & \phi_{x1x1}(N-1) \\ : & .. & .. \\ \phi_{x1x1}(-N+1) & .. & \phi_{x2x1}(0) \end{pmatrix} & \begin{pmatrix} \phi_{x1x2}(0) & : & \phi_{x1x2}(N-1) \\ : & .. & .. \\ \phi_{x1x2}(-N+1) & .. & \phi_{x1x2}(0) \end{pmatrix} \\ \begin{pmatrix} \phi_{x2x1}(0) & : & \phi_{x2x1}(N-1) \\ : & .. & .. \\ \phi_{x2x1}(-N+1) & .. & \phi_{x2x1}(0) \end{pmatrix} & \begin{pmatrix} \phi_{x2x2}(0) & : & \phi_{x2x2}(N-1) \\ : & .. & .. \\ \phi_{x2x2}(-N+1) & .. & \phi_{x2x2}(0) \end{pmatrix} \end{pmatrix}$$

Wiener Filter

$W_{\text{opt} = R^{-1} P}$





Signal to Interferer SIR gain

$$\mathrm{SIR} = \frac{(\text{power gain of target signal})}{(\text{power gain of interference})}$$

where,

$$\text{power gain of target signal(A)} = \frac{(W_{\text{opt\_A}} * \text{SA\_mic1} + W_{\text{opt\_A}} * \text{SA\_mic2})^2}{(\text{SA\_mic1})^2}$$

$$\text{power gain of interference(A)} = \frac{(W_{opt\_A} * SB\_mic1 + W_{opt\_A} * SB\_mic2)^2}{(SB\_mic1)^2}$$

Note that this equation is an example intended to compute SIR_A. For SIR_A and SIRs in the second question the equations are the same, replacing the variable A in each case.

Results

Question 1:

SIR_gain_filter_to_extract_speechA = 30.7732 dB

SIR_gain_filter_to_extract_speechB = 45.9484 dB

Question 2 :

- With white Gaussian noise added to each microphone signal
  - For SNR = 30dB:
    SIR_gain_filter_to_extract_speechA = 19.89 dB
    SIR_gain_filter_to_extract_speechB = 24.88 dB
  - For SNR = 20dB:
    SIR_gain_filter_to_extract_speechA = 12.3787 dB
    SIR_gain_filter_to_extract_speechB = 18.6806 dB
  - For SNR = 10dB:
    SIR_gain_filter_to_extract_speechA = 6.2674 dB
    SIR_gain_filter_to_extract_speechB = 12.5134 dB
  - For SNR = 0dB:
    SIR_gain_filter_to_extract_speechA = 0.4081 dB
    SIR_gain_filter_to_extract_speechB = 6.5675 dB
- The extracted SourceA and SourceB are attached with these names “Q1_SA_Output.wav”, Q1_SB_Output.wav" .

Conclusion

- The optimal multi-channel Wiener solution was able to separate the speech of Speaker A and Speaker B when they are both talking at the same time. (i.e. the extracted sources from the mixture inputs (“Interval 3”) can be heard clearly).
- However, a single channel Wiener solution will not be able to achieve this because the it cant provide the same information(and it’s not enough) as the multi-channel does. components from different sources are not correlated. The total mixtures at the two microphones are not fully correlated and we cannot fully predict one mixture directly from the other mixture.
- The SIR was computed instead of MMSE. Because the MMSE is strongly affected by fluctuations in the power levels.
- In the mixtures, the signals from the same source are fully correlated with each other, but the signals from different sources are not correlated.

- Using 10 coefficients was sufficient to get a very good performance.
- A gradual decrease of performance can be noticed as SNR decreases.