# Some Example Graduation topics

# Multi-Microphone Noise reduction

- Delay and sum beamformer

$$\mathbf{w}(k,l) = \frac{\mathbf{a}(k,l)}{\mathbf{a}^H(k,l)\mathbf{a}(k,l)}$$

- MVDR beamformer

$$\mathbf{w}(k,l) = \frac{\mathbf{R}_{\mathbf{x}}^{-1}(k,l)\mathbf{a}(k,l)}{\mathbf{a}^H(k,l)\mathbf{R}_{\mathbf{x}}^{-1}(k,l)\mathbf{a}(k,l)} = \frac{\mathbf{R}_{\mathbf{n}}^{-1}(k,l)\mathbf{a}(k,l)}{\mathbf{a}^H(k,l)\mathbf{R}_{\mathbf{n}}^{-1}(k,l)\mathbf{a}(k,l)}$$

- Multi-Channel Wiener

$$\mathbf{w}(k,l) = \underbrace{\frac{\sigma_s^2(k,l)}{\sigma_s^2(k,l) + (\mathbf{a}^H(k,l)\mathbf{R}_{\mathbf{n}}^{-1}(k,l)\mathbf{a}(k,l))^{-1}}}_{\text{Single-channel Wiener}} \underbrace{\frac{\mathbf{R}_{\mathbf{n}}^{-1}(k,l)\mathbf{a}(k,l)}{\mathbf{a}^H(k,l)\mathbf{R}_{\mathbf{n}}^{-1}(k,l)\mathbf{a}(k,l)}}_{MVDR}$$

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# Multi-Microphone Noise reduction

- All beamformers depend on the ATF $\mathbf{a}_k$
- How to estimate the ATF $\mathbf{a}_k$?
  - EVD of $\mathbf{R}_X = \mathbf{R}_Y - \mathbf{R}_N$, or, GEVD of $(\mathbf{R}_Y, \mathbf{R}_N)$
  - This is accurate when $(\mathbf{R}_Y$ and $\mathbf{R}_N)$ are known. However, estimation errors severely affect results.
- Graduation topic: ATF estimation using Structured machine/deep learning

  Can we obtain better estimators for $\mathbf{a}_k$ by combining the GEVD and machine learning approaches to take into account estimation errors in $(\hat{\mathbf{R}}_Y$ and $\hat{\mathbf{R}}_N)$
- Graduation topic: ATF estimation using delay doppler domain

  Could be advantageous for moving sources/arrays.

# Multi-Microphone Noise reduction

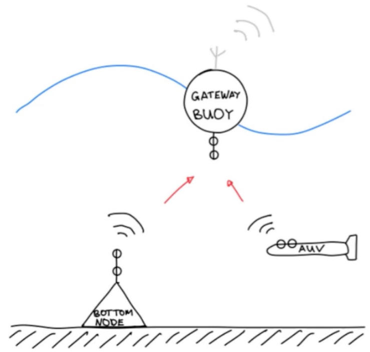
- Multi-microphone noise reduction using tensor decompositions.
- Multi-microphone noise reduction combined with EEG based information.
  - EEG can be used to determine the source of interest. Can we use the EEG to extract other relevant information for the beamformer?
- Personalized modification of the acoustic scene.

# Acoustic Imaging of the Heart Using Microphones

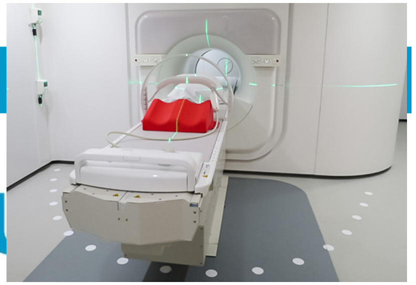
- Imaging (Xray, MRI, Ultrsound, etc.) techniques are relatively expensive and not always available in developing countries.
- Can we develop a simple imaging technique to visualize the different parts of the human heart using an array of microphones.
- Applications:
  - Imaging on the basis of sound of heart and lungs.
  - Store the recordings, and perform offline beamforming to "zoom" in to certain areas.
  - In developing countries, more advanced imaging techniques are not always available in local medical centers and difficult to maintain. This should become a device which is easy to make and maintain, and give first indications of what can be wrong.

# SP/array processing@companies

- LifeTec Group: Data analysis for artificially generated heart tissue
- B&O: Sound field generation, beamforming, etc.
- TNO: underwater acoustics




- Dopple: Audio processing for wireless earbuds
- EMC:
  - SP for understanding atrial fibrillation
  - Optimizing the analysis of auditory event-related potentials in EEG: Detection of diseases and prognosis of development (Child brain lab)
- UMC: Active noise reduction for MRIs
- Sonion: In ear (with hearing aid) based Biomedical Signal Processing



# Some hints for project 2

Constructing the noisy signal:

- For sources $s_p$ and microphone $m$: $x_m[t] = (s_1 * h_{1,m})[n] + \sum_{p=2}^{P} (s_p * h_{p,m})[t]$
- Processing using STFT (i.e., using short time frames of 20 ms): window and FFT the samples $x_m[\text{overlap}(l-1)+1 : \text{overlap}(l-1)+\text{frsize}]$

Estimating Correlation matrices: $\mathbf{R_n}(k,l) = E[\mathbf{n}(k,l)\mathbf{n}^H(k,l)]$ and $\mathbf{R_x}(k,l) = E[\mathbf{x}(k,l)\mathbf{x}^H(k,l)]$

- Assuming ergodicity (sources are spatially invariant) you can estimate $\mathbf{R_n}(k,l)$ e.g. as

$$\hat{\mathbf{R}}_\mathbf{n}(k,l) = \frac{1}{N} \sum_{p=l-M_1}^{l+M_2} \mathbf{n}(k,p)\mathbf{n}^H(k,p)$$

  or as

$$\begin{aligned}
\hat{\mathbf{R}}_\mathbf{n}(k,l) &= \begin{cases} \hat{\mathbf{R}}_\mathbf{n}(k,l-1)\alpha + \mathbf{n}(k,l)\mathbf{n}^H(k,l)(1-\alpha) & \text{target not present} \\ \hat{\mathbf{R}}_\mathbf{n}(k,l-1) & \text{target is present} \end{cases} \\
\hat{\mathbf{R}}_\mathbf{x}(k,l) &= \hat{\mathbf{R}}_\mathbf{x}(k,l-1)\alpha + \mathbf{x}(k,l)\mathbf{x}^H(k,l)(1-\alpha)
\end{aligned}$$

- How to know whether the target is present or not? Either cheat by using directly the mix of interferers, or build a detector.