Homework #2, AA2024-2025: Adaptive interference mitigation on audio signals

Interference mitigation or reduction is crucial in many applications of statistical signal processing. Audio and music-like signals offers an excellent setup to let each one individually evaluate the effectiveness of the specific signal processing method.

One stereo signal $\mathbf{s}(t) = [s_1(t), s_2(t)]^T$ is affected by noise $\mathbf{w}(t) = \mathbf{h}(t) * \mathbf{n}(t)$ that depends on an external noise source $\mathbf{n}(t)$ in unknown way represented by 2x2 filter $\mathbf{h}(t)$ and different settings, the signal model for the sampled signals is:

$$\mathbf{s}_{in}[k] = \mathbf{s}[k] + \mathbf{w}[k]$$

on different Matlab files indicated as `Sin_x` (where `x=a` or `x=b` or `x=c` depending on the file) all sampled at frequency `fs`, purpose of the numerical exercise is to extract the noise-mitigated audio signals. Quality is evaluated by playing signals over the stereo-headset with command `sound(S_est,fs)`, and exercises are with increasing difficulty.

a,b,c) The files `Hw2x.mat` (where `x=a` or `x=b` or `x=c` as above) contains the `Sin_x` affected by different degree of noise, and also a measurement dependent on noise indicated by the variable `Sn_ref_x`. Since these noise-related signals are

$$\mathbf{s}_{ref}[k] = \mathbf{g}[k] * \mathbf{n}[k]$$

one can filters these stereo-signals to suppress them from $\mathbf{s}_{in}[k]$, and get `S_est`.

d,e) The files `Hw2x.mat` (where `x=d` or `x=e` depending on the file) contains only files affected by sinusoid pattern that is varying vs time. To better visualize, one can represent the periodogram over different data segmentations sliding vs recording time, collect each periodogram as one row (say row `k`) of a matrix `P(k,:)` and represent it as `imagesc(P)`, this gives the visual representation of time-frequency analysis (and a nice image comes out). Remove the noise to have a clear estimate of the audio signal.

Suggestion: it is better to tune the cancellation algorithm (learning stage) over a short segment of data, and apply to the whole data only once it has reached the convergence. Exercise d,e, contains also a reduced-size of the whole data, but final exercise is over the complete-data only.