Signal Analysis, Design of Experiments and System Identification
WiSe 2023/2024
6^{th} Computer Exercise
Signal Processing 02

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1. **Real Signals**
   (a) Load the signals (`Signal_01`, and `Signal_02`). Plot the data as time signals, identify one as input x and one as output y of a system.
   (b) Compute the Spectral Power Density (SPD) S_{xx} as the average of the squared Fourier Transforms. Consider the sampling frequency as 4096 Hz.
   (c) Compute and plot the auto-correlation function ϕ_{xx} of the input signal, and ϕ_{yy} of the output signal, (Hint: try the function `autocorr`).
   (d) Compute and plot the cross-correlation ϕ_{xy} of input and output signal (Hint: try the function `xcorr`). Then, compute and plot the cross-spectral density S_{yx}.
   (e) Having cross and power spectral density, the coherence function, is easily obtained and plotted. The coherence function is defined such that

$$\gamma^2(\omega) = \frac{|S_{yx}(\omega)|^2}{S_{yy}(\omega)S_{xx}(\omega)}$$

   (f) Could you now specify the fundamental frequencies of the given signals?

2. **Coherence function in ordinary differential equation**
   (a) Consider at first two noisy sinusoidal functions, and compute the Magnitude-Squared Coherence while considering one of them as input and the second as output (hint: demo_coherence).
   (b) Compute the coherence function while considering a sinusoidal function as input and the solutions obtained from the linear/non-linear Equation of Motion as output (hint: ODE_FFT_Coherence).

3. **Wavelet Transformation:**
   (a) Consider a chirp signal $cos(4x^2)$. Perform discrete wavelet transform (DWT) at level 5 using the Haar/db1 wavelet.
   (b) Expand discrete wavelet coefficient.
   (c) Plot the signal and the expanded discrete wavelet coefficient.
   (d) Apply the same previous instructions for added and concatenated sine signals.

4. **Filters**
   (a) Apply low pass filter on a highly noisy sinusoidal signal (hint: filterOfNoisySine). Change the value of N and intrepret the results.

5. Document observations, findings and conclusions carefully.