Signal Processing for Interactive Systems
Lecture 2: Exercises with hints

Cumhur Erkut
cer@create.aau.dk

February 19, 2024

Last edited: February 19, 2024

Exercise 2.1

Let

$$x_1(n) = \mathrm{e}^{j\omega_0 n} \tag{1}$$
$$x_2(n) = \cos(\omega_0 n) \tag{2}$$

for $n = 0, 1, \ldots, N-1$ with $N = 100$ and $\omega_0 = 0.1\pi$.

(a) Using a computer, compute the K-point amplitude spectra of $x_1(n)$ and $x_2(n)$. Experiment with the size of K. Start with a value of $K = N$ and increase it. What changes when you change K? Why?

> *Hint*: See slides from the lecture.

We now consider the trumpet signal `trumpet`.wav which you can find on Moodle.

(b) Using a computer, compute the K-point amplitude spectrum of the trumpet signal. What can you say about the trumpet signal? Which model is appropriate for describing such a trumpet signal?

> *Hint*: See slides from the lecture.

Exercise 2.2

Linear convolution between two sequences $x(n)$ and $h(n)$ can be performed in both the time- and the frequency-domain. Consider the two sequences

$$x(n) = \cos(\omega_0 n) \tag{3}$$
$$h(n) = \begin{cases} a^n & n \geq 0 \\ 0 & n < 0 \end{cases} \tag{4}$$

for $n = 0, 1, \ldots, N-1$ where $N = 10$, $\omega_0 = 1.1$, and $a = -0.9$.

(a) Using a computer, compute
$$y(n) = (h * x)(n) \tag{5}$$
in the time-domain by summation.

Hint: See slides from the lecture.

(b) Same as in question 1, but now do the convolution in the frequency domain via two FFTs and one iFFT.

Hint: Look at slide 20.

(c) Same as in question 1, but now form the convolution matrix $\boldsymbol{H}$ and compute the convolution via

$$\boldsymbol{y} = \boldsymbol{H}\boldsymbol{x} \ . \tag{6}$$

Hint: See slides from the lecture. You can generate the filter matrix $\boldsymbol{H}$ using the MATLAB command `H = gallery('circul',hzp)';`.

(d) Same as in question 1, but now form the DFT matrix and implement the convolution in the frequency domain via matrix-vector algebra.

Hint: See slides from the lecture. You can generate the DFT matrix using the MATLAB command `F = dftmtx(K);`.