Life Sciences und
Facility Management

ICLS Institut für
Computational Life Sciences

ADLS, Image and Signal Processing, Midterm Exam I

Date: 25. March 2024
Lecturer: Norman Juchler

- Enter your name legibly below.
- Permitted aids: Writing utensils, two A4 pages of summary, calculator, dictionary
- Duration of exam **30 min**
- All sketches, calculations, derivations and considerations must be written on these sheets (front and back) and handed in. Additional sheets are not allowed.
- Provide answers in English
- Clearly cross out invalid answeres and results. If it is unclear which result applies, no points are awarded.
- Do not write with pencil, colored pencil or other erasable pens

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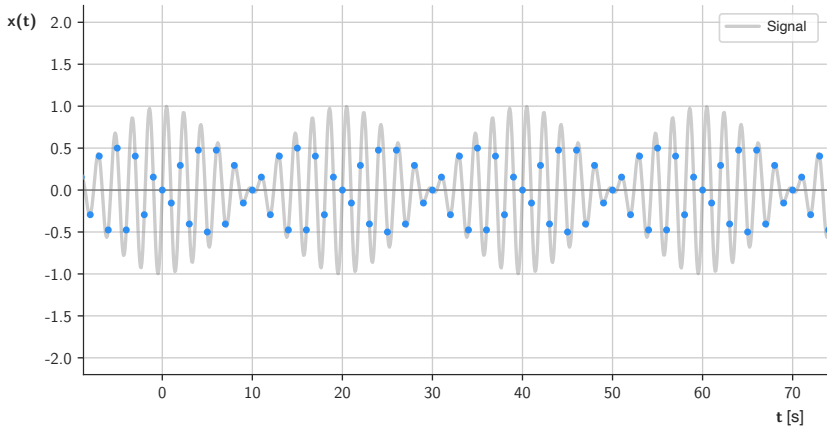
Family name: **First name:**

Exercise	1	2	3	4	Total
Maximum	7	6	9	7	29
Result					

Grade: _____ **Good luck!**

Question 1

7 P.



a) **Period and frequency** (3 P. possible)

Take a look at the periodic, continuous-time signal $x(t)$ above. Provide the following information for that signal:

- Period T
- Frequency f
- Angular frequency ω

Also specify the units for these measures.

b) **Phenomena** (2 P. possible)

What phenomena does the dashed blue signal represent? What can you say about the gray signal?

c) **Nyquist-Shannon** (2 P. possible)

Assume that the above continuous-time signal $x(t)$ is composed of two sine curves with frequencies f of 10 and 11 Hz. What is the minimum frequency f_s at which we should sample the signal so that we can reconstruct the signal faithfully? Round the resulting frequency to the nearest whole number (which is still a valid sampling frequency).

Question 2

6 P.

a) **Applications of DSP** (3 P. possible)

Name three different applications for digital signal processing that are used routinely in the context of a hospital, a farm, or a beverage production facility. For each application, provide:

- The name or description of the application
- The signal being processed

b) **Frequency content and rhythm** (3 P. possible)

You are studying a digital recording of the hit "Yellow Submarine" by the Beatles. You know from a public database of musical tempos (www.bpmdatabase.com) that the song is played at 112 beats per minute (BPMs). Let's assume that a drum beat is clearly audible 112 times per minute.

Answer the following questions:

1. Rhythm refers to the temporal pattern or regularity present in a signal. Is it therefore sufficient to study the beat in the spectrum? Justify your answer in 1-2 sentences.
2. Do you know a method to verify the "beats per minute" information using Python / your computer?

Question 3

9 P.

a) **Convolution** (4 P. possible)

Let's convolve a discrete filter $h[n]$ with a signal $x[n]$.

Answer the following questions:

1. Which Python function (from `numpy` or `scipy`) would we most likely use?
2. If we want to implement our own function `my_convolve()` to convolve two signals, what exactly would we do? Complete the code structure below. (Line out the code using words and function names, the code does not have to be functional. Explain what the steps mean.)

b) **Window filters** (3 P. possible)

In the course, we have encountered different window filters.

1. What are the main effects of window filtering as we have learned about it?
2. Name three different window types.

c) **Signal operation** (2 P. possible)

Let's be given a discrete-time signal `x` with $N > 100$ samples. Which operation do we apply with the following line of code?

```
x[::5]
```

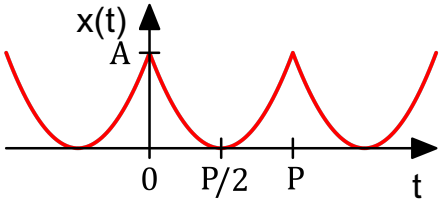
Listing 1: Code structure for task a)

```python
import numpy as np
import scipy.fft as fft

def my_convolve(h, x):
    # Step 1) ...
    # Step 2) ...
    # Step 3) ...
    # ...
```

Question 4

6 P.



a) **Fourier series** (3 P. possible)

Have a look at the above image that shows a so-called parabola signal $x(t) = \frac{4A}{P^2}(t - \frac{P}{2})^2$ with period P and amplitude A (with $P, A > 0$). Which of the following coefficients describe the Fourier series most accurately? Explain your choice!

You do not have to solve any integrals here.

Option A) $A_0 = 0, \quad A_k = \frac{2}{\pi^2 k}, \quad B_k = \frac{4A}{\pi^2 k^2}$

Option B) $A_0 = 0, \quad A_k = \frac{4A}{\pi^2 k^2}, \quad B_k = 0$

Option C) $A_0 = \frac{A}{3}, \quad A_k = \frac{4A}{\pi^2 k^2}, \quad B_k = 0$

b) **Complex numbers** (3 P. possible)

Compute the result of the following multiplication:

$$q = z \cdot z, \quad \text{with } z = 5 - 4i$$

Questions:

1. What is the result q?
2. What happens to the phase of z when z is multiplied by itself?