Exercise 4: Time Series Analysis – Part V

- Filtering in the time domain -

Group:	Surname, Given Name:	Matriculation number:	Signature*:

*** With my signature I declare that I was involved in the elaboration of this exercise.**

Deadline: 07.01.2026

Objective

This exercise deals with time series analysis applying filtering techniques in the time domain.

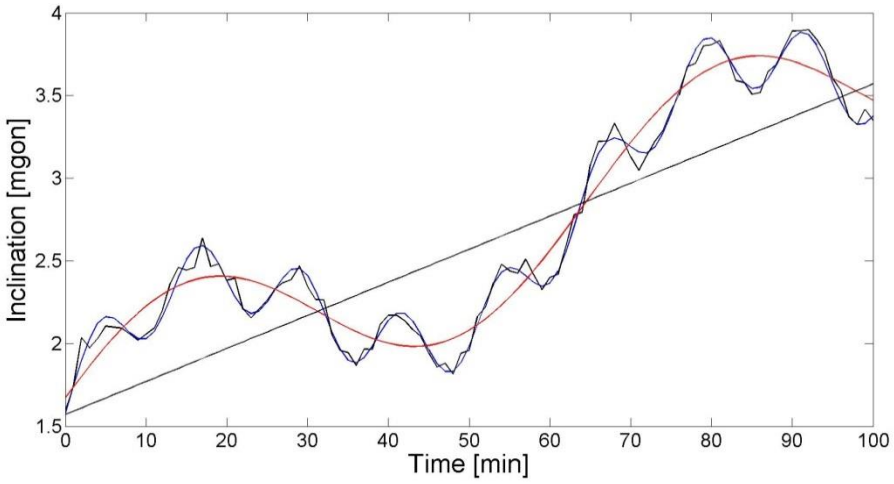

Figure 1: Inclination measurements

Task 1:

- In the file "E*xercise4-1.txt*" the inclination measurements depicted in Figure 1 are given, while the first column represents the time axis and the second column the $x(t)$ values
- Load and plot the time series
- Apply a moving average filter with a filter length of $\tau = [5\ 10\ 15\ 20\ 25]$
- Remove each resulting moving average from the given time series and plot each reduced time series
- Interpret and discuss the results

Task 2:

- In the files "E*xercise4-2_1.txt*" to "E*xercise4-2_4.txt*" four time series are given, while the first column represents the time axis and the second column the $x(t)$ values
- Load and plot the time series
- Please filter each time series using the following three configurations:
  - A moving average filter with window length $\tau = 25$.
  - A Savitzky-Golay filter with window length $\tau = 25$ and polynomial degree $p = 2$.
  - A moving least squares filter with window length $\tau = 25$, a polynomial degree $p = 2$ and Gaussian weighting.
- Plot the resulting filtered series and interpret and discuss the results

Task 3:

- In the file "E*xercise4-3.txt*" a time series are given, while the first column represents the time axis and the second column the $x(t)$ values. The time series was generated using the following model:

$$x = \frac{1}{2}t^2 + \sin(6\pi t) + N(0,0.1)$$

  where $N(0,0.1)$ denotes Gaussian noise with mean 0 and variance 0.1.
- Load and plot the time series
- Please determine the first and second derivative of the time series using the following configurations:
  - Using finite differences via the Matlab function *diff*.
  - Using your own moving least squares approach.

  Hint: Please do not forget to rescale your filtered derivative estimates by sampling interval dt
- Plot the resulting derivative estimates and compare them to the true derivatives. Interpret and discuss the results.

Task 4:

- Acceleration measurements are given in the file "E*xercise4-4.txt*" where the first column represents the time axis in $[\mathrm{s}]$ and the second column the $x(t)$ values in $[\mathrm{m/s^2}]$
- Load and plot the time series
- Background: These acceleration measurements have been carried out during an experiment while the sensor has been placed on an oscillating table. The amplitude of this oscillation was set to $5\ \mathrm{mm}$.
- In order to derive displacements, these acceleration measurements need to be integrated twice.
    - Please develop your own moving least squares approach to numerically integrate the acceleration time series
    - Plot the resulting displacements obtained from double-integrated acceleration data
- Remove any existing trend from the displacement time series
    - Select an appropriate filter to obtain displacements that match the predefined amplitude of $5\ \mathrm{mm}$
    - Plot the detrended and filtered displacement time series.
- Interpret and discuss the results