von KARMAN INSTITUTE FOR FLUID DYNAMICS

Research Master 2022/2023

Signal Processing (SP, Part II)

Exam Problem

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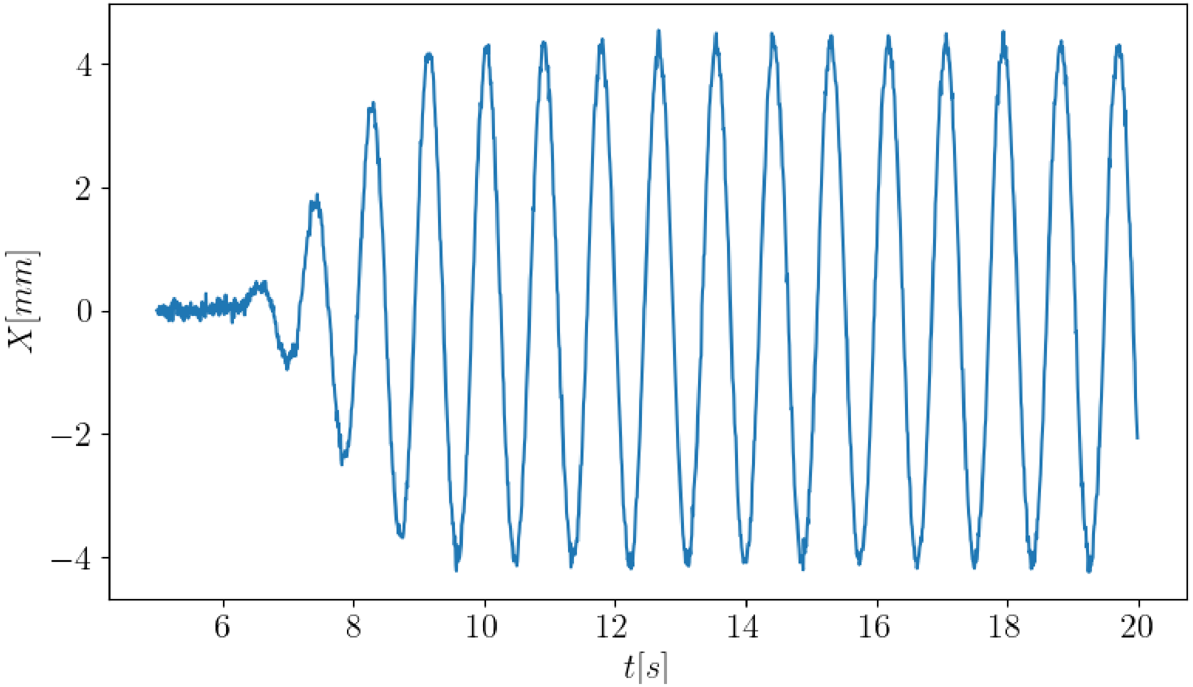
Problem Set

The VKI's SHAKESPEAR Table

Your team is conducting sloshing experiments in the SHAKESPEARE facility (SHaking Aparatus for Kinetic Experiments of Sloshing Projects with EArthquake REproduction) and you have measured the imposed displacement of the table using the Optical Displacement Systems (ODS).



Here is the signal that you have measured (displacement versus time). The data is provided in an excel file.

Note: consider the signal from time t=5s (that is, discard the first 500 entries)

GOAL: you want to compute the velocity and, most importantly, the acceleration imposed to the tank. This is the key information to analyze the sloshing dynamics and to reproduce it in a CFD simulation.

Questions/Assignments

1. **Compute the velocity and acceleration by differentiating the signal**. For the differentiation, pick any finite difference formulation you consider appropriate. Then, study the frequency content of the three signals (displacement, velocity and acceleration). What do you see and why?

2. **Use the FIR or IIR filters** to control the noise amplification in the differentiation. Select filter type, order and application (recursive vs convolution) as you think is most appropriate. You can use a non-causal approach to avoid phase lag, and you are free to manipulate the boundaries in any way you consider appropriate.
 Comment briefly on what are the main challenges.

3. **Compute derivatives in the Fourier Domain.** Computing derivatives in the frequency domain is equivalent to performing multiplications. This is the essence of spectral and pseudospectral methods in CFD. Show it using the DFT definition and then using Python. Is this true everywhere? Compute velocity and acceleration using spectral differentiation + filtering.