Exercise 06: Data Processing and Analysis

It is assumed that experimental data of the known carriage-pendulum system were recorded, but the pendulum dynamics play no role here.
The carriage is driven by a DC motor. The system at rest reacts to a constant voltage with an increase in speed up to a certain final value.

General note: Use the given source code (and take a look at the solution if you are stuck)

1. load the file `measurementdata.dat` (2d-array in txt-format) and load the individual quantities into 1d arrays each and create an visualization to get an overview of the time evolution of each quantity.
   Hint 1: Meaning of the columns: time (t), displacement x, voltage V, current (I). **Hint 2:** `plt.plot(t, x1)`

2. Due to the measurement procedure, the flow direction of the current was not recorded. However, it is known from physical considerations that the current (except for the noise) must have the same sign as the voltage. Create a new array which contains the correct signal of the current I.

   Hint: This can be solved in one (short) line. See slides on array boolean array indexing.

3. Create an array with two columns which contains **the indices** of those time points when a voltage pulse starts (first column) or ends (second column).

   The array then has the form (N, 2), where N is the number of voltage pulses.

   Hint 1: See slide for `np.diff` **Hint 2:** use `np.arange(N)` to create an array of all possible indices and then use boolean indexing

4. Select those current readings that (for example) belong to the third voltage pulse plot a histogram of the values, and infer the statistical distribution of the noise (uniformly distributed, normally distributed, ...).

5. For each "current block", calculate the mean value and save these values in a new array, which has the same length as the original current array but only contains the blockwise averaged current values.

6. Plot these mean values with the corresponding voltage value in an U-I diagram. Using linear regression, calculate the conductance (slope of the straight line in the U-I-diagram) and the offset current.

7. Determine the velocity and acceleration from the displacement signal and store each one in a separate array.

   Note: `np.diff`

8. Each positive voltage pulse has a start time t_0 and an end time t_1. During the time interval $[t0, t1]$ the cart moves. For each such movement draw the corresponding curve of acceleration versus velocity.

9. Interpolate between these curves using `griddata` and display the result graphically (imshow, see image).
   Background: The goal is that a voltage can be read from the graph for each pair of values of velocity and acceleration. This means: For a given actual velocity and a desired acceleration, the diagram returns the necessary voltage to achieve this acceleration. This can be used to effectively control the motor.

10. Write a function `calc_voltage(v, a)` that approximately calculates the necessary voltage from velocity and acceleration to calculate the necessary voltage.

11. Load the file `upswing.npy` (with `numpy.load`). It contains a (simulated) measurement of the pendulum beeing swung up to the upper equilibrium point. Use the function `calc_voltage` to determine the voltage evolution over time which the motor needs to reproduce that swingup motion.
    Note: Meaning of the columns: time, displacement, velocity, angle, angular velocity, acceleration of the carriage.