

# Machine Learning per il Calcolo Scientifico

## Third laboratory exercises

### General guide

For each laboratory, an incomplete Python notebook will be provided with exercises (steps) that must be completed in the given order (some of the exercises will be needed in future laboratories). In step zero, all the Python packages that are needed in order to complete the notebook are listed. This PDF includes the text for the exercises and the expected outcomes for each step. While following the notebook is recommended, you are also welcome to attempt the exercises without using it.

### Step Zero

Here are the required Python (<https://www.python.org/>) packages for this laboratory:

- PyTorch (<https://pytorch.org/>)
- Numpy (<https://numpy.org/>)
- Matplotlib (<https://matplotlib.org/>)
- ipympl (<https://matplotlib.org/ipympl/>)

### Exercise one: Solve a simple ODE

$$\begin{cases} \frac{dy(t)}{dt} = -2y(t), & t \in (0, 1) \\ y(0) = 1 \end{cases}$$

- Using DeepNet (DNN.py) define a FNN with 3 layers and 5 neurons, with tanh as the activation function
- Using torch.rand define the training points (50 points); the test points are instead defined with torch.linspace (100 points)
- Complete the functions eval\_loss\_ode and eval\_loss\_IC.
- Following the documentation define the optimizer.
- Complete the training loop (2000 epochs).
- Visualize the results obtained by completing the plots written in the notebook

### Exercise two: Non-linear boundary value problem

$$\begin{cases} -\frac{d}{dx} \left[ (1+u^2) \frac{du}{dx} \right] = -2\pi \cos(\pi x)^2 \sin(\pi x) + \pi^2 \sin(\pi x) (\sin(\pi x)^2 + 1), & x \in (0, 2). \\ u(0) = u(2) = 0. \end{cases}$$

- Using DeepNet (DNN.py) define a FNN with 5 layers and 20 neurons, with tanh as the activation function
- Using torch.rand define the training points (200), while using torch.linspace for test (500)
- Complete the functions eval\_loss\_ode and eval\_loss\_pt.
- Following the documentation define the optimizer.
- Complete the training loop (5000 epochs).
- Visualize the results obtained by completing the plots written in the notebook