Machine Learning – July 22, 2021

Information:

1. Answers must be explicitly marked with the question they refer to (e.g., 2.1 for question 1 of exercise 2). Cumulative answers which refer to more questions at once will be considered as answering one question only (and will be evaluated as such).
2. (in person) Use two different sets of sheets, one for questions 1-3 and one for questions 4-6. Write your name, lastname and matricola on all papers you submit.

Time limit: **2 hours 15 minutes**.

EXERCISE 1

Consider the notion of *overfitting*:

1. Provide a formal and general definition, without referring to any particular model.
2. Show two examples of overfitting in two distinct models.
3. For one of the models above, explain how the problem can be mitigated.

EXERCISE 2

Consider the following dataset, containing the samples of a function f:

x_1	f
0.6	2
1.2	4
1.5	5

1. Based on the available data, select a reasonable model for learning f, explicitly indicating its parameters.
2. Show an optimal and a non-optimal solution, explicitly indicating, for each of them, the corresponding value of the loss function.

EXERCISE 3

1. Give a short explanation of the *kernel trick/kernel substitution*. What is the necessary condition for applying the kernel trick?
2. Provide an example of its application. In detail:
   - draw a suitable dataset for binary classification in 2D;
   - discuss which kernel you would use for this dataset;
   - show graphically a possible solution of such a kernel-based model.

EXERCISE 4

1. Describe the convolution stage of a Convolutional Neural Network (CNN), illustrating all the elements involved and highlighting the trainable parameters.
2. Discuss the properties of sparse connectivity and parameter sharing for CNN.

EXERCISE 5

1. Describe the K-means algorithm in a formal way (i.e., with precise mathematical formulas and equations), including: input and output of the algorithm, its main steps, and the termination condition.
2. Describe common drawbacks of this algorithm (i.e., situations in which solutions are not optimal)
3. Draw a 2-D data set and the corresponding (qualitative) K-means solution highlighting some of the drawbacks illustrated in the previous point.

EXERCISE 6

1. Explain the goal of dimensionality reduction. Give an example of dimensionality reduction using a problem of your choice.
2. Explain the difference between Principal Component Analysis and Autoencoders in dimensionality reduction.