

# Machine Learning – September 17, 2025

Matricola

Last Name

First Name

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1. No books, slides, written notes are allowed during the exam.
  2. 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 will be evaluated as answering one question only.

Time limit: **2 hours**.

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## EXERCISE 1

1. Discuss the following statement: “*Accuracy is not always a good performance metric for classification*”.
2. Provide a numerical example to motivate your answer.

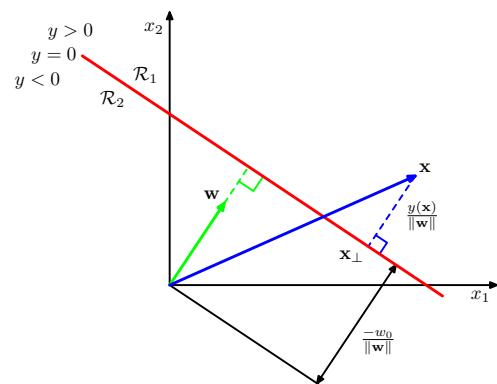
## EXERCISE 2

A robotic device is used to sort two types of objects. Its perception component is a binary classifier with two continuous variables in input  $f : \mathbb{R}^2 \rightarrow \{C_1, C_2\}$ . Let  $D$  be a suitable supervised dataset for this problem.

1. **Formally** describe a probabilistic generative model based on maximum likelihood (e.g., Gaussian Naive Bayes) for such a classification problem, assuming Gaussian distributions.
2. Provide invented values for the parameters of the model described above.
3. Qualitatively draw the model with invented parameters described above and show two new samples  $\mathbf{x}_1$ ,  $\mathbf{x}_2$ , such that  $\mathbf{x}_1$  is predicted as  $C_1$  and  $\mathbf{x}_2$  is predicted as  $C_2$ .

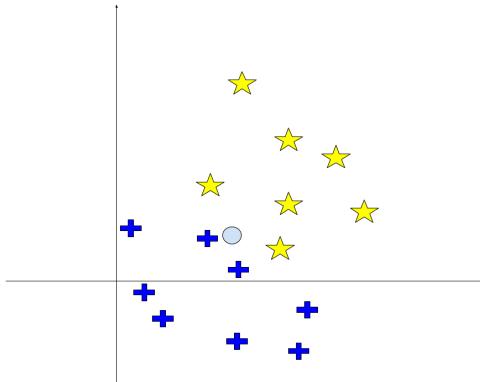
## EXERCISE 3

1. Describe the maximum margin principle used by Linear SVM classification. Consider the figure on the right where  $\mathbf{w}$  is the normal vector of a boundary and  $r = \frac{y(\mathbf{x})}{\|\mathbf{w}\|}$  the distance of a point  $\mathbf{x}$  from the boundary. Describe which quantity should be maximized and with respect to which parameter in order to obtain a boundary having the largest margin.
2. Draw an example of a 2-D binary linear classification problem showing qualitatively: i) a generic solution, and ii) a maximum margin solution computed by SVM.



#### **EXERCISE 4**

1. Describe the K-nearest neighbors (K-NN) algorithm for classification.
2. Given the dataset on the right for the two classes  $\{\text{star}, \text{plus}\}$ , determine the answer of K-NN for the query point indicated with symbol o for  $K=1$ ,  $K=3$ , and  $K=5$ . Motivate your answer, showing (with a graphical drawing) which instances contribute to the solution.



#### **EXERCISE 5**

Describe the following algorithms used for training artificial neural networks:

1. Backpropagation
2. Stochastic Gradient Descent

For each algorithm, clearly define (in a formal way) inputs and outputs and describe the main steps of execution.

#### **EXERCISE 6**

1. Describe the concept of bagging in the definition of an ensemble model. Describe precisely the training procedure for such a model and the final formula used for prediction.
2. Discuss the difference between bagging and voting, highlighting in particular the use of different types of models.