MACHINE LEARNING

EXAM SD-TSIA 210 2023 - DURATION : 3H

No document is authorized, nor computers. The answers must be precise and short. French or English are accepted.

1 - SUPERVISED CLASSIFICATION

We consider the probabilistic and statistical framework of supervised classification where X is a random vector on $\mathbb{R}^d$, $d \geq 1$ and Y is a binary random variable with values in $\{-1, +1\}$. A random sample $\mathcal{S}_n = \{(X_1, Y_1), \ldots, (X_n, Y_n)\}$, with n independent copies of the pair (X, Y) of joint probability distribution P.

1. Define the empirical risk of a classifier calculated using $\mathcal{S}_n$. Explain the principe of *Empirical risk minimization.*
2. What is overfitting ? What is the underlying idea of the methods designed to avoid it ? Give at least two examples of such methods (for any kind of model) to illustrate.

2 - SUPPORT VECTOR MACHINES

We are still considering the framework of binary supervised classification.

1. What optimization problem do we need to solve in the primal space to find the Optimal Margin Hyperplane, e.g. a linear SVM when data are noisy ?
2. Give the definition of a positive definite kernel, and explain its key property, used in SVMs to deal with data that are non linearly separable.

3 - ENSEMBLE METHODS

1. Give the pseudocode for the Random Forest algorithm. What's the difference with the Bagging technique ?
2. Describe the Out-of-bag samples and the Variable Importance method in Bagging.

4 - INTRODUCTION TO DEEP LEARNING

1. Give a formal description of a multilayer perceptron with one hidden layer, taking as inputs data points in $\mathbb{R}^d$, that is aimed at performing multinomial classification, with K classes. Precisely define the parameters of the model.
2. Using the model you previously described as supporting example, explain, in your own words, the principle of back-propagation and what purpose it serves (*it is not necessary here to apply back-propagation to your network !*).
3. Optimizing deep neural networks is in general difficult. Give and explain the idea behind 3 innovations made to ease training of deep neural models.