Machine Learning – Test - November 26, 2018

Time limit: **2 hours**.

Last Name ..... First Name ..... Matricola .....

Note: if you are not doing the exam for ML 2018/19, write below name of exam, CFU, and academic year (when you were supposed to attend the course). Please specify also if you are an Erasmus student.

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EXERCISE 1

The following data have been collected and we want to learn the general concept *Acceptable*, by using Decision Tree Learning.

House	Furniture	Nr rooms	New kitchen	Acceptable
1	No	3	Yes	Yes
2	Yes	3	No	No
3	No	4	No	Yes
4	No	3	No	No
5	Yes	4	No	Yes

1. Formalize the learning problem: decribe exactly the target function to learn and the dataset.
2. Describe qualitatively how attributes are chosen when building a Decision Tree.
3. Simulate the execution of ID3 algorithm on the data set above and generate the corresponding output tree.

Note: point 3 can be answered even if point 2 is not properly addressed, by using any invented method (or invented numbers) for the selection of the variables.

EXERCISE 2

1. Provide a formal definition of a maximum likelihood (ML) hypothesis
2. Comment the following statement: *in a classification problem, the class returned by the ML hypothesis on a new instance x is always the most probable class.*

EXERCISE 3

Briefly describe a linear classification method and discuss its performance in presence of outliers. Use a graphical example to illustrate the concept.

EXERCISE 4

Consider a dataset containing 3D points belonging to two classes C_1 and C_2. Each set of points belonging to a class is assumed to be normally distributed, namely $P(\mathbf{x}|C_i) \simeq \mathcal{N}(\mathbf{x}; \boldsymbol{\mu}_i, \boldsymbol{\Sigma})$ (same covariance matrix for both the classes).

1. Describe the conditional probability of class C_1 considering a data instance $\mathbf{x}$. (Hint: apply the Bayes rule)
2. Given $\alpha = \ln \frac{p(\mathbf{x}|C_1)P(C_1)}{p(\mathbf{x}|C_2)P(C_2)}$, and the sigmoid function $\sigma(\alpha) = \frac{1}{1+\exp(-\alpha)}$, express $P(C_1|\mathbf{x})$ in terms of σ
3. What are the model parameters? Which is the size of the model (number of independent parameters)?

EXERCISE 5

Describe the Markov property of Markovian models representing dynamic systems. Describe the difference between a Markov Decision Process (MDP) and a Hidden Markov Model (HMM). Draw and explain the graphical models of MDP and HMM.

EXERCISE 6

A car driver in Rome has to move from one side of the Tiber river to the other very often every day. There are three possible alternative paths passing to three different bridges and the paths are known. The driver wants to minimize the time to reach the target location, but due to traffic conditions, it is not guaranteed that the shortest path is also the quickest way. Moreover, traffic conditions are unpredictable, fully observable and (quasi-)stationary.

1. Describe a complete model for this problem based on MDP, specifying all its elements.
2. Describe how to solve the problem based on Reinforcement Learning and determine the exact training rule to use to learn the best behavior.
3. Discuss the strategy for balancing exploration and exploitation.