DIPARTIMENTO DI ELETTRONICA, INFORMAZIONE E BIOINGEGNERIA

Politecnico di Milano

Machine Learning (Code: 097683)

February 12, 2018

Name:
Surname:
Student ID:
Row: Column:

Time: 2 hours 30 minutes | Prof. Marcello Restelli | Maximum Marks: 34

- The following exam is composed of **10 exercises** (one per page). The first page needs to be filled with your **name, surname and student ID**. The following pages should be used **only in the large squares** present on each page. Any solution provided outside these spaces will not be considered for the final mark.
- During this exam you are **not allowed to use electronic devices** like laptops, smartphones, tablets and/or similar. As well, you are not allowed to bring with you any kind of note, book, written scheme and/or similar. You are also not allowed to communicate with other students during the exam.
- The first reported violation of the above mentioned rules will be annotated on the exam and will be considered for the final mark decision. The second reported violation of the above mentioned rules will imply the immediate expulsion of the student from the exam room and the **annulment of the exam**.
- You are allowed to write the exam either with a pen (black or blue) or a pencil. It is your responsibility to provide a readable solution. We will not be held accountable for accidental partial or total cancellation of the exam.
- The exam can be written either in **English** or **Italian**.
- You are allowed to withdraw from the exam at any time without any penalty. You are allowed to leave the room not early than half the time of the duration of the exam. You are not allowed to keep the text of the exam with you while leaving the room.
- **Three of the points will be given on the basis on how quick you are in solving the exam. If you finish earlier than 45 min before the end of the exam you will get 3 points, if you finish earlier than 30 min you will get 2 points and if you finish earlier than 15 min you will get 1 point (the points cannot be accumulated).**

Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10	Time	Tot.
/ 5	/ 5	/ 5	/ 2	/ 2	/ 2	/ 2	/ 2	/ 3	/ 3	/ 3	/ 34

Exercise 1 (5 marks)

Describe the supervised learning techniques called **ridge regression** and **LASSO** for regression problems.

Exercise 2 (5 marks)

Describe the UCB1 algorithm. Is it a deterministic or a stochastic algorithm?

Exercise 3 (5 marks)

Describe the differences existing between the Q-learning and SARSA algorithms.

Exercise 4 (2 marks)

Which criteria would you consider for model selection in each one of the following settings:

1. A small dataset and a space of simple models;
2. A small dataset and a space of complex models;
3. A large dataset and a space of simple models;
4. A large dataset and a trainer with parallel computing abilities.

Justify you choices.

Exercise 5 (2 marks)

Categorize the following ML problems. For each one of them suggest **a set of features** which might be useful to solve the problem and **a method** to solve it.

1. Recognise handwritten characters;
2. Identify interesting features from an image;
3. Teach a robot how to play bowling;
4. Predicting car values for second-hand retailers.

Exercise 6 (2 marks)

State if the following are applicable to generic RL problems or MAB problems. Motivate your answers.

1. We should take into account state-action pairs one by one to estimate the value function;
2. Past actions you perform on the MDP might influence the future rewards you will gain;
3. The Markov property holds;
4. The time horizon of the episode is finite.

Exercise 7 (2 marks)

After training a perceptron classifier on a given dataset, you find that it does not achieve the desired performance on the training set, nor the validation one. Which of the following might be a promising step to take? Motivate your answers.

1. Use an SVM with a Gaussian Kernel;
2. Add features by basing on the problem characteristics;
3. Use linear regression with a linear kernel, without introducing new features;
4. Introduce a regularization term.

Exercise 8 (2 marks)

The generic definition of a policy is a stochastic function $\pi(h_i) = \mathbb{P}(a_i|h_i)$ that, given a history $h_i = \{o_1, a_1, s_1, \dots, o_i, a_i, s_i\}$, provides a distribution over the possible actions $\{a_i\}_i$.

Formulate the specific definition of a policy if the considered problem is:

1. Markovian, Stochastic, Non-stationary;
2. History based, Deterministic, Stationary;
3. Markovian, Deterministic, Stationary;
4. History based, Stochastic, Non-stationary.

Exercise 9 (3 marks)

Suppose we collect data for a group of giant slalom ski racers containing, for each racer, the number of hours spent training x_1, her/his best time during practice x_2 (in seconds), and a variable telling if she/he won the race t (1 for winning, 0 for not-winning). We fit a logistic regression model $\hat{t} = \sigma(w_0 + w_1 x_1 + w_2 x_2) = \frac{1}{1+e^{-(w_0+w_1x_1+w_2x_2)}}$ to predict the probability that a racer wins given its performance during training and produce estimated coefficients: $w_0 = -6$, $w_1 = 0.1$ and $w_2 = -0.02$.

1. Provide an interpretation for the coefficient w_0. How does this model classify a racer new to the game?
2. Estimate the probability that a racer wins, given that she/he trained for 100h and her/his best time being 1m 40s.
3. Do you think that values of the coefficient w_2 makes sense in this problem? Why?

z	-5	-4.5	-4	-3.5	-3	-2.5	-2	-1.5	-1	-0.5	0
$\sigma(z)$	0.006	0.01	0.02	0.029	0.047	0.075	0.119	0.182	0.268	0.377	0.5
z	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5
$\sigma(z)$	0.622	0.731	0.817	0.88	0.924	0.953	0.971	0.982	0.989	0.993	0.996

If the value you need to solve the second point is not among the ones we provided, approximate the $\sigma(z)$ value with the one from the nearest z.

Exercise 10 (3 marks)

Consider the hypothesis space of the decision trees with $n = 4$ binary features with at most $k = 3$ leaves (in this case you have less than $n^{k-1}2^{2k-1}$ different trees) and the problem of binary classification. Assume to have a learning algorithm which is able to perfectly classify the training set of $N = 28$ samples.

1. What is the lowest error ε you can guarantee to have with probability greater than $1 - \delta = 1 - 2^{-5}$?
2. How many samples do you need to halve this error? Do we need some property on the classifier of these new samples so that the error bound is still valid?

Justify your answers properly. Moreover, recall that:

$$\mathbb{P}(\exists h \in \mathcal{H},\ L_{true}(h) > \varepsilon) \leq |H|e^{-N\varepsilon}$$

and that $\frac{1}{\log_2(e)} \approx 0.694$ and $\frac{1}{\log_7(e)} = 1.94$.