732A96/TDDE15 ADVANCED MACHINE LEARNING

EXAM 2024-10-29

Teacher

Jose M. Peña. He will visit the rooms for questions.

Grades

- For 732A96 (A-E means pass):
  - A=19-20 points
  - B=17-18 points
  - C=14-16 points
  - D=12-13 points
  - E=10-11 points
  - F=0-9 points
- For TDDE15 (3-5 means pass):
  - 5=18-20 points
  - 4=14-17 points
  - 3=10-13 points
  - U=0-9 points

In each question, full points requires clear and well motivated answers and commented code.

Instructions

- This is an individual exam. No help from others is allowed. No communication with others is allowed. Answers to the exam questions may be sent to Urkund.
- This is an anonymous exam. Do not write your name on it.
- The answers to the exam should be submitted in a single PDF file. You can make a PDF from LibreOffice (similar to Microsoft Word). You can also use Markdown from RStudio (no support is provided though). Include important code needed to grade the exam (inline or at the end of the PDF file).

Allowed help

Everything on the course web page. Your individual and group solutions to the labs. This help is available on the corresponding directories of the exam system.

1. Probabilistic Graphical Models (5 p)

The files `TentaOkt2019.pdf` and `Solutions231019.R` give respectively a description and a BN solution to the Monty Hall problem.

You are now asked to extend the problem to the case where there are four doors. As before, there is one car behind one of the doors and goats behind the others.

You are also asked to extend further the four door problem to the case where there are two hosts (Monty Hall a and b) that choose a door each to open. They choose the doors independently of each other, i.e., they may both choose the same door to open.

Finally, perform exact inference to solve the problem. That is, say that you initially choose the first door and the hosts choose both the second door to open, then should you change to the third door? Or to the fourth? If the hosts choose the second and third doors to open, should you change to the fourth door?

2. Hidden Markov Models (5 p)

This exercise is a modification of lab 2, and thus you may want to reuse/adapt your code. You are asked to model the behavior of a robot that walks around a ring. The ring is divided into five sectors. The robot works in two modes. In mode 1, the robot is in one of the sectors and decides with equal probability to stay in that sector or move to the next sector. In mode 2, the robot is in one of the sectors and decides with probability 0.3 to stay in that sector and with probability 0.7 to move to the next sector. After deciding whether it stays or moves, the robot also decides with probability 0.8 to continue operating in the same mode and with probability 0.2 to change mode. You do not have direct observation of the robot. However, the robot is equipped with a tracking device that you can access. The device is not very accurate though: If the robot is in the sector i, then the device will report that the robot is in the sectors $[i-1, i+1]$ with equal probability.

You are asked to build a HMM for the scenario described above, simulate it for 100 time steps and use the 100 observations obtained to determine if the robot is working in mode 1 or 2 after 100 time steps. Assume that the robot starts working in mode 1.

3. Reinforcement Learning (5 p)

The Q-learning algorithm that you implemented in lab 3 consists of just one agent aiming to learn the optimal q-table. Now, you are asked to implement a multi-agent version of Q-learning. Specifically, you are asked to implement a Q-learning algorithm that consists of two collaborating agents such that (i) each agent has its own q-table that it updates within each episode, (ii) the agents exchange their q-tables at the end of each episode to compute the average q-table which replaces their individual q-tables. Run the multi-agent version of Q-learning in the environment A from lab 3. Comment the results. The easiest way to solve this exercise may be by duplicating (i.e., one duplicate for each agent) some of the functions in your solution to lab 3.

Finally, give one advantage and one disadvantage of the multi-agent Q-learning algorithm.

4. Gaussian Processes (5 p)

Recall from the slides in the file `GP_L1_Regression.pdf` that we assumed a GP prior zero mean function. You are now asked to assume that the prior mean function is the sine function (`sin(x)` in `R`) and derive the GP posterior mean. For this, you should revisit the properties of Gaussian distributions in slide 6 and how they were used in slide 17 of the mentioned file. Then, you should implement it to predict the posterior mean on the Canadian wages dataset. For this, we recommend you to adapt the code in the file `KernLabDemo.R`. You should predict the wage for the ages in the training data, and also for the ages 66-100 where no training data exist. You should do it for $\ell = 1$ and $\ell = 100$, and comment your results.