Reinforcement Learning: Coursework Assignment 1 (*Semester 2, 2014/2015*)

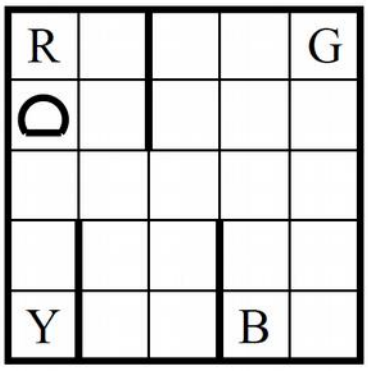
Instructions

- This homework assignment is to be done *individually*, without help from your classmates or others (except the RL tutors). Plagiarism will be dealt with strictly as per University policy.
- Solve all problems and provide your complete solutions (with adequate reasoning behind each step) in a report in computer-printed or *legibly* handwritten form.
- Before you start to write a program, read all questions below carefully.
- Only the report will be marked. The code itself will not be marked, but will used to clarify any questions arising from the report. If you are using code that you have not written yourself, then acknowledge this appropriately (you do not have to mention the code provided for the tutorials). Include references to books and papers that you have been using (you do not have to cite the RL lecture slides or reading material required for this course).
- Use graphical representations wherever suitable. If you use numerical output for demonstrating your results, make sure that the numbers are appropriately rounded and presented in an accessible way. If your problem involves randomness, explain why your result is representative for most of the possible realisations of the underlying random effects.
- Include your code in the submission (preferably Matlab). If you are presenting numerical results in your report, specify all major numerical parameters that were involved in the generation of the data shown.
- This assignment will count for 10% of your final course mark.
- Please submit your assignment by 4 pm on 5th March as a paper copy to ITO as well as an electronic version (including your code) via the submit system (directory "rl").

Questions

This assignment studies a benchmark problem for RL algorithms, namely the taxi problem (Dietterich, 2000). Below is the specification given in Ref. (Dutech, 2005)

- State variables: taxiLocation {1, ..., 25}, passengerLocation {1, ..., 5} (i.e. waiting at pickup/drop-off {R,G,B,Y} or in the taxi), drop-offLocation {1, ..., 4} (i.e. {R,G,B,Y}).
- Initialisation of a trail: Taxi is uniformly randomly in any of the 25 grid squares, passengerLocation is uniformly randomly in one of the 5 passenger states, dropoffLocation is uniformly randomly one of the 4 drop-off locations
- Termination of a trial: Passenger was successfully dropped-off
- Actions: 1: go north, 2: go south, 3: go west, 4: go east, 5: pick up passenger, 6: drop off passenger
- Reward: -1 for an attempted movement (whether it is successful or blocked by a wall), -1 for a successful pick-up, 0 for a successful drop-off, -10 for an attempted drop-off with no passenger or at the wrong location, -10 for an attempted pick-up at the wrong location (or if the passenger is already in the taxi).



1. Before you start programming, provide some rough estimates the following quantities
    - typical time horizon of the problem
    - mean (immediate) reward for a good policy
    - maximal value of a state-action pair
    - number of trials that a standard algorithm will need in order to find a good solution

   Explain how you arrive at the estimates and how these estimates can be used in the design of the algorithm. Discuss also whether the problem is deterministic or stochastic. (15/100)
2. Solve the problem using *Q*-learning.
    - Represent your solution using an example (Fix e.g. initial passenger position at "Y", goal at B, and plot the value of the spatial states and the best action for each state). (10/100)
    - Compare the results obtained by the algorithm to the estimates for mean reward and maximal value (see question 1) (10/100)
    - Consider the time course of the values and the reward and define a convergence time for the algorithm. (10/100)
3. Solve the problem using SARSA and answer the same questions as above. (15/100)
4. Discuss, possibly using numerical examples, how the convergence time depends on the exploration strategy. (10/100)
5. Compare the performance of *Q*-learning and SARSA on the Taxi problem. (10/100)
6. The goal problem is described by a number of non-positive reward values. Would it be possible to reduce the learning time by using a different set of reward values (all other parameters of the algorithm remaining the same)? (10/100)
7. Taking into account the compositional structure of the problem, discuss how the learning speed can be improved? Consider that partial policy followed by the cab is essentially the same when moving, e.g., towards pick-up site "R" in order to pick up a passenger and when doing this in order to drop her off at site "R". Explain how you would take this structure into account. (10/100)
8. Add a paragraph of conclusions drawn from the solution of these problems.

References:

Dietterich, T. G. (2000). Hierarchical reinforcement learning with the MAXQ value function decomposition. *J. Artif. Intell. Res. (JAIR)*, *13*, 227-303.

Dutech, A., Edmunds, T., Kok, J., Lagoudakis, M., Littman, M., Riedmiller, M., Whiteson, S. (2005) Reinforcement learning benchmarks and bake-offs II. *Workshop at Advances in Neural Information Processing Systems conference*.