Departamento de Informática
Universidad Carlos III de Madrid

Grado en Ingeniería Informática

Artificial Intelligence

May 2017

General instructions

- Time assigned to the exam is **2.5 hours**
- Teachers will not answer any question about the exam
- You cannot leave the classroom during the exam, unless you have finished it
- Exams cannot be answered using a pencil

Theory questions

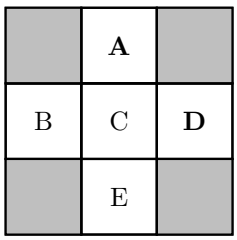
We expect very short answers.

1. (1 point) What are the main differences between Markov Chains, HMMs, MDPs and POMDPs?
2. (1 point) Classify each element in the following list of input/output elements as sensor or actuator: speaker, stereo camera, mouse readings, voice recognition, motor in the leg of a humanoid robot, sending email, GPS, and accelerometer.
3. (1 point) A robot moves in a grid by using horizontal, vertical and diagonal moves to the adjacent tiles to the one that it occupies at each time step. Each movement has a cost of one, except for the move in diagonal that has a cost of 1.4. How would you define an admissible heuristic function that estimates the number of moves that it will take to move from any position in the grid to a given goal position? Provide a formula.
4. (1 point) How is conflict resolution handled in fuzzy logic?
5. (1 point) In the previous case, assume that the robot has some probability of failing in its movement and ending up in a different tile than the intended one. If we would like to estimate the position of the robot at each time step and we can use as input the odometry of the robot (number of rotations done by each of its wheels since the last reading), name at least two techniques from the ones covered in class to solve this task.
6. (2 points) We want to generate a control system for a drone. It should take as input a set of sensor readings from the current state of the drone (height, wind speed, estimated GPS position, ...) and generate as output a control signal that specifies what it should do (move up/down, left/right, or straight). Formally describe how would you generate such control mechanism using machine learning.
7. (2 points) In the previous case, how would you solve the task using fuzzy logic? Provide at least one example of each element used.

8. (1 point) MyCar S.L. is building an autonomous car using a rule-based system to decide at each time step whether to stay in the same lane, change to the right lane, change to the left lane, turn right in an intersection, turn left in an intersection, or stop. In order to make that decision, it uses as input the number of cars in the same lane of the car, number of cars in the left/right lane, and number of cars in the left/right street in the intersection. Each of these numbers can have as values 0, 1, ..., 10 and more-than-10. How many different states can we create in such a system? And how many rules can we define using those elements?

Project question (1 point)

Consider the following *gridworld* problem, namely *grid*, where cells A and D are goal states with a reward of -10 and +10 respectively; and the observed training episodes:



Training Session 1
(B, East, C)
(C, East, D)

Training Session 2
(B, East, C)
(C, East, D)

Training Session 3
(E, North, C)
(C, East, A)

Training Session 4
(E, North, C)
(C, North, A)

1. Compute the learned transition functions for $T(B, East, C)$, $T(C, East, A)$, and $T(C, East, D)$.

Considering the values of the learned transition functions, we execute the Value Iteration algorithm using the following parameters:

```
ptyhon gridworld.py -a value -i 1 -g grid --discount 1
```

Once the execution is finished:

2. What is the returned value of `computeQValueFromValues(C, East)`?
3. What is the returned value of `computeActionFromValues(C)`?

Sketch of solutions

This is just a sketch of a possible valid way of answering the exam questions. It does not mean they are the only valid answers.

1. Summary

	Observability	
actions	**full**	**partial**
no	Markov chains	HMM
yes	MDP	POMDP

2. Sensors: stereo camera, mouse readings, voice recognition, GPS, and accelerometer

   Actuators: speaker, motor in the leg of a humanoid robot, and sending email.

3. $h(n) = 1.4 \times min(\Delta_x, \Delta_y) + max(\Delta_x, \Delta_y) - min(\Delta_x, \Delta_y)$

   where $\Delta_x = \mid x_n - x_{\text{goal}} \mid$ and $\Delta_y = \mid y_n - y_{\text{goal}} \mid$

   Euclidean distance is a worse option. Manhattan distance is not admissible in this case.

4. Composition through aggregation. Either the max or sum functions can be used on the output of all fuzzy rules matchings.

5. HMMs, POMDPs, machine learning (neural networks, Naïve Bayes, ...)

6. You need to collect examples where each example is composed of the values of N attributes (from the sensors readings) and a class (control signal). You would need to describe how to obtain those examples (random actions and labeling the class according to whether they were the right ones, letting a human control the drone for some time, ...). Then, you would have to shortly explain the training (learning) procedure.

7. You need to describe the input and output variables, their values, examples of some membership functions for both, and examples of fuzzy rules.

8. States: 12^5, rules: 6×12^5

Solution to question on the project

$$
\begin{aligned}
T(B, East, C) &= \frac{2}{2} && \text{(number of times of (B,East,C) and (B,East) on training)} \\
T(C, East, A) &= \frac{1}{3} && \text{(number of times of (C,East,A) and (C,East) on training)} \\
T(C, East, D) &= \frac{2}{3} && \text{(number of times of (C,East,D) and (C,East) on training)}
\end{aligned}
$$

$$
\begin{aligned}
V(C) &= \max \left\{ \begin{array}{l} Pr(A|East \wedge C)(-10 + \gamma\, V^0(C)) + Pr(D|East \wedge C)(10 + \gamma\, V^0(C)), \\ Pr(A|North \wedge C)(-10 + \gamma\, V^0(C)) \end{array} \right\} \\
&= \max \left\{ \begin{array}{l} 0.33(-10 + 1(0)) + 0.66(10 + 1(0)), \\ 1(-10 + 1(0)) \end{array} \right\} \\
&= \max\{3.33, -10\} = 3.33
\end{aligned}
$$

`computeQValueFromValues(C, East)` returns 3.33

`computeActionFromValues(C)` returns *East*