Instituto Superior Técnico

Artificial Intelligence and Decision Systems (IASD)

Final exam, 2008/2009

First date

NAME: ______________________________

NUMBER:

- The answers should be given **exclusively** on these sheets
- Read carefully each question before answering
- Justify all your answers (except the multiple choice ones)
- This exam is to be executed **without any** consultation (a small *formulæ* can be found in the last page)
- **Exam duration: 3 hours**

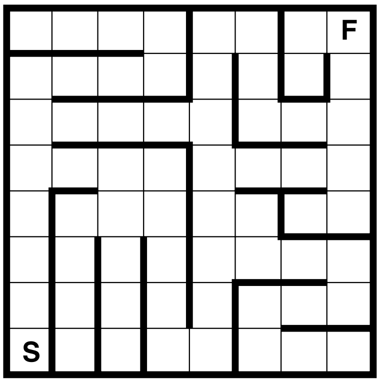
1. [**1 val**] Which of the following elements make necessarily part of an agent, according to the definition? (more than one answer might be correct)

   - ☐ environment
   - ☐ actuators
   - ☐ critic
   - ☐ goals
   - ☐ sensors

2. [**1 val**] While solving a CSP (Constraint Satisfaction Problem), the application of the Forward Checking technique has (in general) as effect(s) (more than one answer might be correct)

   - ☐ reduction of the number of successors
   - ☐ reduction of the maximum tree depth
   - ☐ reduction of the solution depth
   - ☐ reduction of the spatial complexity
   - ☐ reduction of the temporal complexity

3. Consider the labyrinth indicated in the figure below. It is intended to obtain the shotest path from the entrance S to the exit F, using state space search techniques.



(a) **[1 val]** Define the state space and a successor function for this problem.

(b) **[1 val]** Answer if it is indispensable to include the path from the beginning in the state representation.

(c) **[1 val]** Characterize this problem with respect to the branching factor.

(d) **[2 val]** Consider these possible heuristics for this problem, taking as unitary the cost of a movement from one cell to an adjacent one: given the location (x, y),

$$h_1(x, y) = |8 - x| + |8 - y|$$

$$h_2(x, y) = \sqrt{(8 - x)^2 + (8 - y)^2}$$

$$h_3(x, y) = 2h_2(x, y)$$

Which of these heuristics (if any) are admissible? Which would you choose to better solve the problem?

4. From a knowledge base containing the following first order logic sentences:

$$\forall_x \text{ Healthy}(\text{Heel}(x)) \Rightarrow \text{CanRun}(x)$$

$$\forall_x \forall_y \text{ Damaged}(x, y) \Rightarrow \neg\text{Healthy}(y)$$

$$\neg\text{CanRun}(\text{Achilles})$$

$$\forall_x \exists_y \neg\text{Healthy}(x) \Rightarrow \text{Damaged}(y, x)$$

(a) **[2 val]** Translate the knowledge base to the clausal normal form (CNF).

(b) **[2 val]** Is it possible to prove that $\exists_x \text{Damaged}(x, \text{Heel}(\text{Achilles}))$? If yes, prove using resolution.

5. Consider a planning problem using the STRIPS language consisting of two actions: FlyTo(x, y) (x flies to airport y) and Checkin(x, y) (x checks in at the airport y). The predicate At(x, y) denotes that x is at the airport y, and the predicate Checkedin(x, y) denotes that x checked in at the airport y.

   (a) **[2 val]** Specify in STRIPS the two actions refered above, assuming that one can only fly (FlyTo) after checking in at the departure airport.

   (b) **[1 val]** If the initial state is $\text{At}(\text{Alice}, \text{Lisbon})$, what is the action sequence to achieve the goal $\text{At}(\text{Alice}, \text{Frankfurt})$?

   (c) **[1 val]** What is the state of the knowledge base after performing the action sequence answered in the previous question?

6. Consider a Markov decision process (MDP) with 3 states (A, B, and C), and 2 actions (*stay* and *change*). The action *stay* maintains the state, while the *change* one changes the state to one of the other states, with equal probability. The rewards are given by this table

R(A)	R(B)	R(C)
0	-2	1

(a) [**1 val**] Write the transition function for the state A (e.g., as a table). Note that, by symmetry, the function for the other states is identical.

(b) [**2 val**] Assuming that the value iteration algorithm converged to the following values

U(A)	U(B)	U(C)
7.05	5.67	10

Determine the optimal policy. (*Suggestion:* use the maximization of the expected utility principle).

(c) **[2 val]** Perform one step of the policy iteration algorithm, taking the action *stay* for any state as the initial policy, and a discount factor of 0.9.

Formulæ

$$N = 1 + b + \cdots + b^d$$

$$U(s) = R(s) + \gamma \max_a \sum_{s'} T(s,a,s')U(s')$$

$$U_{i+1}(s) \leftarrow R(s) + \gamma \max_a \sum_{s'} T(s,a,s')U_i(s')$$

$$U^\pi(s) = R(s) + \gamma \sum_{s'} T(s,\pi(s),s')U^\pi(s')$$

$$\pi^*(s) = \arg\max_a \sum_{s'} T(s,a,s')U(s')$$