Aalto University, Department of Computer Science JR & TR

ICS-E4000 Artificial Intelligence **April 7, 2016**

Problem 1 Explain briefly (1-4 sentences) (10 pts)

1. What is the horizon effect and what causes it?
2. Explain what are *mixed equilibria* in games in normal form (strategic form)? Can there be a mixed equilibrium for a game with a unique pure-strategy equilibrium obtained by iterated strict dominance? How/why?
3. How does WA* algorithm differ from A*?
4. How does changing the discount factor γ from 1 to a smaller value change the behaviour of the agent in sequential decision making problems?
5. What is technological singularity?

Problem 2 Sets and Relations in the Propositional Logic (2+2+3+3 = 10 pts)

Write formulas that represent the following.

1. Set of your choice with cardinality $2^7 - 1$ (with the bits represented by A,B,C,D,E,F,G)
2. Set of your choice with cardinality $\frac{2^7}{2}$ (with the bits represented by A,B,C,D,E,F,G)
3. The binary relation $\{(00,01),(11,11)\}$ on bit-vectors with 2 bits (with the bits in a bit-vector represented by A,B)
4. Action with precondition A=1 and effect B := 1 (for state variables A,B,C)

Problem 3 Decision Making under Uncertainty (10 pts)

Consider a student Sam who has the choice to buy (b=1) or not buy (b=0) a textbook for a course. He will either master (m=1) or not master (m=0) the material in the book and either pass (p=1) or not pass (p=0) the course (course has an open-book final exam). Sam has a utility function $U = -1b + 20p$. He estimate probabilities as follows:

$$P(p = 1|b = 1, m = 1) = 0.9 \quad (1)$$
$$P(p = 1|b = 1, m = 0) = 0.5 \quad (2)$$
$$P(p = 1|b = 0, m = 1) = 0.8 \quad (3)$$
$$P(p = 1|b = 0, m = 0) = 0.3 \quad (4)$$
$$P(m = 1|b = 1) = 0.9 \quad (5)$$
$$P(m = 1|b = 0) = 0.7 \quad (6)$$

Draw the expectimax search tree and use it to solve the optimal decision (whether to buy or not buy the book).

Problem 4 Adversarial Search (10 pts)

This problem exercises the basic concepts of game playing, using tic-tac-toe (noughts and crosses) as an example. We define X_n as the number of rows, columns, or diagonals with exactly n X's and no O's. Similarly, O_n is the number of rows, columns, or diagonals with just n O's. The utility function assigns +1 to any position with $X_3 = 1$ and -1 to any position with $O_3 = 1$. All other terminal positions have utility 0. For nonterminal positions, we use a linear evaluation function defined as $Eval(s) = 3X_2(s) + X_1(s) - (3O_2(s) + O_1(s))$.

- Approximately how many possible games of tic-tac-toe are there?
- Show the whole game tree starting from an empty board down to depth 2 (i.e., one X and one O on the board), taking symmetry into account.

- Mark on your tree the evaluation of all the positions at depth 2.
- Using the minimax algorithm, mark on your tree the backed-up value for the positions at depths 1 and 0, and use those values to choose the best starting move.
- Circle the nodes at depth 2 that would *not* be evaluated if alpha-beta pruning were applied, assuming the nodes are generated in the optimal order for alpha-beta pruning.

Problem 5 Planning (10 pts)

Let's define a simple planning language, with both Boolean and real-valued state variables, to which we can refer through equalities $b = 0$ and $b = 1$ (Boolean variables), and through inequalities $r < c$, $r \leq c$, $r > c$, $r \geq c$, $r = r_1$ where c is a real constant (for real-valued state variables.)

Actions consist of a precondition and effects. Preconditions are Boolean combinations of the above equalities and inequalities (with connectives $\wedge$, $\vee$ and $\neg$). Effects are assignments of the following forms.

$b := 0 \quad b := 1$

$r := c \quad r := r_1 + c \quad r := r_1 - c \quad r := r_1$

Here c is a real constant, b is a Boolean state variable, and r and r_1 are real-valued state variables.

An example action would be the following.

PRE: $b = 0 \vee r \leq 13$
EFF: $r := r + 1$; $b := 1$; $d := 0$

Formalize the following problem in this planning language. There is a package that can be moved by a truck in a city of size 10 km by 10 km, where the truck can move 500 meters at a time north, south, east or west. Initially the truck is at the north-east corner of the city (coordinates $10, 10$), the package is at $2.5, 2.0$, and the package should be moved to $5, 5.5$. Initially the tank of the truck has 6 liters of fuel, and each move of 500 meters consumes 0.2 liters of fuel. There is a gas station at $3, 3$, and the tank of the truck can be made full at the gas station. The tank capacity is 100 liters.

1. List all state variables.
2. Specify the initial state (values of state variables).
3. Give the goal formula.
4. Give all the actions for formalizing the scenario: moving the truck (giving one of the four is enough: the other three are similar), loading the package into the truck, unloading it, and filling the tank of the truck.

Make sure that you include *all* required effects of each action, and that the actions accurately represent the scenario.

Hint: For the package use the real-valued state variables p_x, p_y for the location (whenever outside the truck), and the Boolean variable *inside* for indicating whether it is inside the truck or not.

Hint: Don't spend time thinking what the plan will look like, if it exists. This is not what we are asking.

The name of the course, the course code, the date, your name, your student number, and your signature must appear on every sheet of your answers.

Please note the following: your exam will be graded only if you have completed at least three of the obligatory home assignments before the exam, and will have completed all four by April 22!