Course "**Fundamentals of Artificial Intelligence**" EXAM TEXT

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Name (please print):

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Matriculation Number:

1

In the following FOL formulas, let Q, R, P, and $>, \leq, <, \geq$ denote predicates,
g, h, f, F_1, F_2, F_3 and $+, -, \cdot, /$ denote functions,
x, y, z, x_1, x_2, x_3 denote variables,
A, B, C, C_1, C_2, C_3 and $0, 1, 2, 3, 4$ denote constants.
For each of the following facts, say if it is true or false.

(a) The FOL formula $(2 > 4)$ is unsatisfiable.

(b) The FOL formula $\forall x.((x > 2) \rightarrow (x > 1))$ is valid.

(c) The FOL formula $(\exists x_1.\neg Q(x_1)) \leftrightarrow (\neg \forall x_1.Q(x_1))$ is valid

(d) The FOL formula $(\forall x_2 \exists x_1.Q(x_1, x_2)) \rightarrow (\exists x_1 \forall x_2.Q(x_1, x_2))$ is valid.

[SCORING [0...100]:

- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

2

Given the following symbols, representing concept, relation and individual names in the alien language of the remote planet Sgotz:

- a set of primitive $\mathcal{ALCQ}$ concept names: {Perun, Malle, Feale, Dotot, Egier}
- a set of $\mathcal{ALCQ}$ relation names: {haCidod}
- a set of $\mathcal{ALCQ}$ individual names: {Lok, Jud, Etu, Dib, Ate, Bek, Mop, Gop}

and the following $\mathcal{ALCQ}$ $\mathcal{T}$-box $\mathcal{T}$ and $\mathcal{A}$-box $\mathcal{A}$:

$\mathcal{T}$			$\mathcal{A}$
Perun		$\langle primitive\ concept \rangle$	Etu : Woana; Mop : Woana; Gop : Woana; Lok : Woana;
Feale		$\langle primitive\ concept \rangle$	
Malle		$\langle primitive\ concept \rangle$	Jud : Mnana; Ate : Mnana; Bek : Mnana; Dib : Mnana;
Dotot		$\langle primitive\ concept \rangle$	
Egier		$\langle primitive\ concept \rangle$	Ate : Dotot; Etu : Dotot
Woana	$\equiv$	Perun $\sqcap$ Feale	
Mnana	$\equiv$	Perun $\sqcap$ Malle	Mop : Egier; Gop : Egier; Lok : Egier
Moeth	$\equiv$	Woana $\sqcap \exists$haCidod.Perun	
Faeth	$\equiv$	Mnana $\sqcap \exists$haCidod.Perun	$\langle$Jud, Etu$\rangle$: haCidod; $\langle$Jud, Ate$\rangle$: haCidod;
Panet	$\equiv$	Perun $\sqcap$ haCidod.Perun	$\langle$Jud, Mop$\rangle$: haCidod;
Gamae	$\equiv$	Moeth $\sqcap$ haCidod.Panet	
Gafae	$\equiv$	Faeth $\sqcap$ haCidod.Panet	$\langle$Etu, Gop$\rangle$: haCidod; $\langle$Etu, Bek$\rangle$: haCidod;
Gapan	$\equiv$	Panet $\sqcap$ haCidod.Panet	$\langle$Etu, Dib$\rangle$: haCidod; $\langle$Etu, Lok$\rangle$: haCidod;

For each of the following $\mathcal{ALCQ}$ queries to $\mathcal{T} \cup \mathcal{A}$, say if it is true or false.

(a) Jud : Gapan $\sqcap \forall$haCidod.Moeth
(b) Jud : Faeth $\sqcap \exists$haCidod.Panet
(c) Jud : Faeth $\sqcap (\geq 2)$haCidod.Dotot
(d) Etu : Moeth $\sqcap (\geq 3)$haCidod.Egier

[SCORING [0...100]:

- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

3

For each of the following facts about conditional independence, say if it is true or false.

(a) If B and C are conditionally independent given A, then $\mathbf{P}(B, C, A) = \mathbf{P}(B|A)\mathbf{P}(C|A)\mathbf{P}(A)$

(b) If B and C are conditionally independent given A, then $\mathbf{P}(B, C, A) = \mathbf{P}(B)\mathbf{P}(C)\mathbf{P}(A)$

(c) If B and C are conditionally independent given A, then $\mathbf{P}(B, C|A) = \mathbf{P}(B, C)$

(d) If B and C are conditionally independent given A, then $\mathbf{P}(B, A|C) = \mathbf{P}(B, A)$

[SCORING [0...100]:

- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

4

Given a generical search problem, assume time and space complexity are measured in terms of

b : maximum branching factor of the search tree

m : maximum depth of the state space (assume m is finite)

s : depth of the shallowest solution

Assume also that all steps cost are 1.
For each of the following facts, say if it is true or false

(a) Depth-First Search with loop-prevention requires $O(b^s)$ memory to find a solution.

(b) Depth-First Search with loop-prevention requires $O(b^s)$ steps to find a solution.

(c) Breadth-First Search is optimal

(d) Breadth-First Search requires $O(b^m)$ memory to find a solution.

[SCORING [0...100]:

- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

5

Consider propositional logic (PL); let G, F, E, D, C, B, A be atomic propositions
We adopt the set notation for resolution rules, s.t. Γ denotes a set of clauses.

For each of the following statements, say if it is true or false.

(a) The following is a correct application of the PL general resolution rule:

$$\frac{\Gamma,\quad (\quad B \vee \neg E \vee \quad G),\quad (\neg B \vee \neg G \vee \quad D)}{\Gamma,\quad (\neg E \vee \quad D)}$$

(b) The following is a correct application of the PL general resolution rule:

$$\frac{\Gamma,\quad (\quad E \vee \neg D \vee \neg B),\quad (\neg G \vee \neg E \vee \neg D)}{\Gamma,\quad (\neg D \vee \neg G \vee \neg B)}$$

(c) The following is a correct application of the PL clause-subsumption rule:

$$\frac{\Gamma,\quad (\quad B \vee \quad G),\quad (\quad B \vee \neg E \vee \quad G)}{\Gamma,\quad (\quad B \vee \neg E \vee \quad G)}$$

(d) The following is a correct application of the PL unit-resolution rule:

$$\frac{\Gamma,\quad (\quad E),\quad (\quad B \vee \neg E \vee \quad G)}{\Gamma,\quad (\quad E),\quad (\quad B \vee \quad G)}$$

[SCORING [0...100]:

- +25pts for each correct answer
- -25pts for each incorrect answer
- 0pts for each unanswered question

]

6

Given the following Sudoku scenario:

1	2	3	4	5	6	7	8	9	
1		8							A
2				5					B
9						4	6		C
8								6	D
7								4	E
5								3	F
6	8	1							G
	7	2		3					H
		9							I

(a) Apply the AC-3 algorithm. Describe in the right sequence the domains of unassigned nodes whose domains become unary after one run of AC-3. (E.g.:
$D_{A1} := \{3\}$,
$D_{B1} := \{7\}$,
...)

(b) Can AC-3 reduce to unary the domains of nodes $B3$ and $C3$?

(c) After one run of AC-3, is the resulting graph arc-consistent?

[SCORING: [0...100], 50pts for correct answer (a), 25pts each for correct answer (b) and (c). No penalties for wrong answers..]

7

Consider the following CNF formula in PL:

$$
\begin{array}{llllll}
(& E & \vee \neg B & \vee & N) & \wedge \\
(& A & \vee H & \vee & C) & \wedge \\
(\neg H & \vee & I & \vee & A) & \wedge \\
(\neg L & \vee & C & \vee \neg M) & & \wedge \\
(\neg G & \vee \neg A & \vee \neg E) & & & \wedge \\
(& E & \vee \neg G & \vee & A) & \wedge \\
(& E & \vee \neg F & \vee \neg A) & & \wedge \\
(& I & \vee & L & \vee & M) \wedge \\
(\neg N & \vee & L & \vee & M) &
\end{array}
$$

Consider the WalkSAT algorithm, with probability parameter $p = 0.2$. Suppose at a given step the current assignment is

$$\{ \ A, \ \ B, \ \ C, \ \ D, \neg E, \neg F, \ \ G, \neg H, \ \ I, \neg L, \neg M, \neg N \}.$$

Assuming the most-likely event happens, describe what the assignment is after the next step.

[SCORING: [0...100], 100 pts for a correct answer, no penalties for wrong answers.]

8

An experienced doctor has to cope with an epidemic of covid19, where 70% of people of the area have been infected. She considers the following possible symptoms:

Symptom #1: nausea;
Symptom #2: headache;
Symptom #3: fever.

She models the cause-effect relation as a **Naive Bayes Model scenario**, s.t the effects are considered conditionally independent given the cause, and she knows from statistics the following data: [1]

$P(nausea\|\ \ covid19)$	$= 0.7$
$P(nausea\|\neg covid19)$	$= 0.1$
$P(headache\|\ \ covid19)$	$= 0.3$
$P(headache\|\neg covid19)$	$= 0.2$
$P(fever\|\ \ covid19)$	$= 0.6$
$P(fever\|\neg covid19)$	$= 0.2$

She is informed that one patient has headache and fever but not nausea. Compute the probability that such patient has contracted covid19.

Notice: *the problem must be solved my using the Naive Bayes Model scenario. Any attempt to use any other technique will be considered incorrect.*

[SCORING: [0...100], 100 pts for correct answer, no penalties for wrong answers.]

[1] The data here are pure fantasy and are not supposed to correspond to actual medical data.

9

(a) Describe as Pseudo-Code the Depth-Limited Search and Iterative-Deepening procedures.

(b) calling b the branching factor and s the depth of the shallowest solution,

- what is the time complexity of the Iterative-Deepening procedure?
- what is the memory complexity of the Iterative-Deepening procedure?

[SCORING: [0...100], 75 pts for a correct answer to question (a), 25 pts for correct answer to question (b); no penalties for wrong answers.]

10

(a) Describe as Pseudo-Code the specialized solving procedure for tree-structured CSPs.

(b) Say if the following sentence is true or false, and briefly explain why.

- It requires polynomial time in worst-case if the input constraint graph has no loops.

[SCORING: [0...100], 75 pts for a correct answer to question (a), 25 pts for correct answer to question (b); no penalties for wrong answers.]

11

Use *hill climbing* for solving the maximization problem over (x, y) with the following objective function:

y								
7	**0**	**2**	**3**	**4**	**4**	**2**	**1**	**0**
6	**1**	**1**	**4**	**5**	**5**	**3**	**2**	**1**
5	**2**	**3**	**5**	**8**	**6**	**4**	**2**	**3**
4	**3**	**5**	**6**	**9**	**10**	**6**	**5**	**1**
3	**3**	**4**	**7**	**10**	**9**	**6**	**4**	**1**
2	**2**	**2**	**4**	**6**	**7**	**5**	**4**	**3**
1	**1**	**1**	**3**	**5**	**4**	**3**	**1**	**1**
0	**0**	**1**	**2**	**3**	**4**	**2**	**2**	**0**
	0	1	2	3	4	5	6	7 x

The next state is selected among the neighbors with strictly higher objective function value with *probability proportional to their objective function value*. Neighbors of (x, y) are sorted as follows:

$$(x-1, y-1), (x, y-1), (x+1, y-1), (x-1, y), (x+1, y), (x-1, y+1), (x, y+1), (x+1, y+1)$$

The choice vector is: $[1/4, 3/4]$.

The *initial state* is: $(7, 0)$.
For each step in the resolution process report (1) the current state; (2) the list of candidate next states.

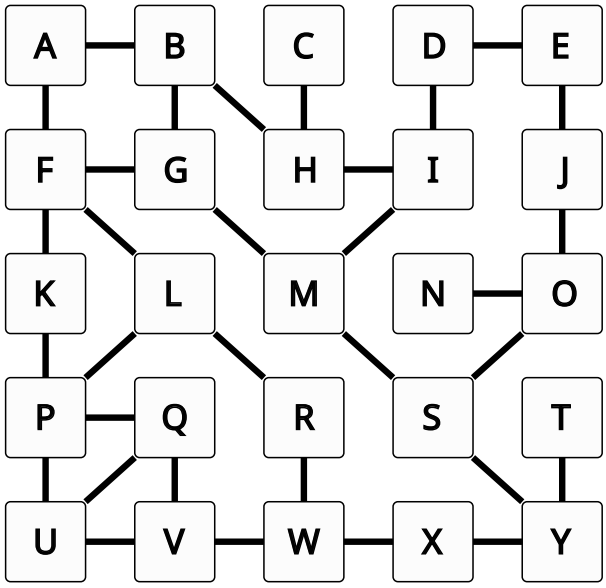
[SCORING: [0...100], 100pts for a fully correct solution, -20pts for each error in the resolution process. The score cannot go below 0..]

12

In the following state graph, apply *breadth-first search* and report for each step:

- the node extracted from the frontier;
- the nodes added to the frontier in the current step.

Actions are sorted according to the (ascending) alphabetical order of the destination.



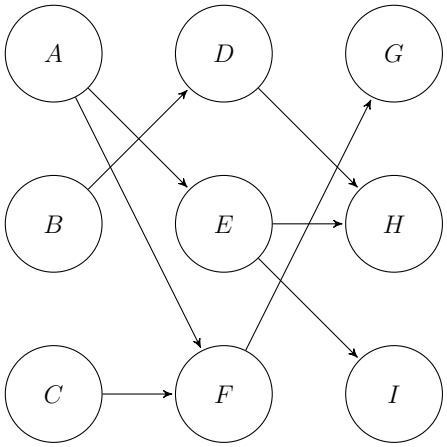
Start: **M** - Goal: **P**

[SCORING: [0...100], 100pts for a fully correct solution, -10pts for each error in the resolution process. The score cannot go below 0..]

13

Consider the following actions with durations / dependencies:

a	duration(a)
A	2
B	1
C	2
D	3
E	2
F	3
G	1
H	2
I	3



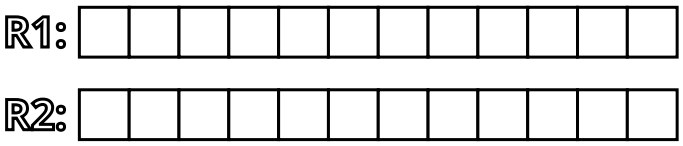
1) Compute the earliest / latest possible start time (ES/LS) for each action using the Critical Path method. [40pts.]

Assume that completing each action requires one unit of a reusable resource:

2) Report an optimal schedule given 2 reusable resources in the grid below. [40pts.]

3) What would be the optimal execution time given 1 reusable resource? [10pts.]

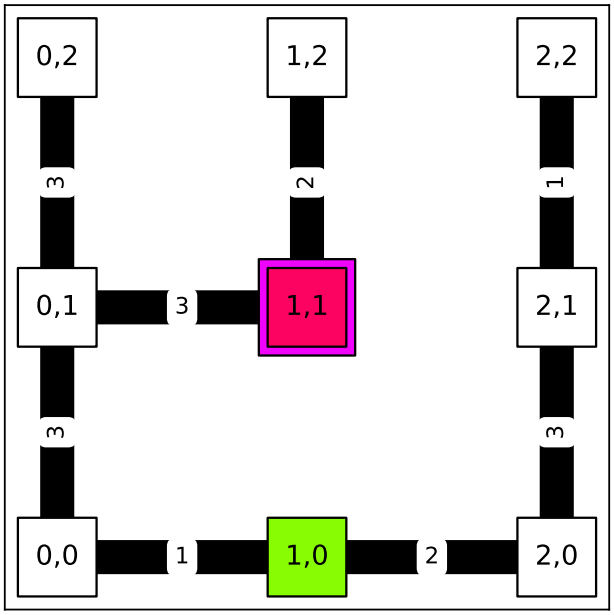
4) What would be the optimal execution time given infinite resources? [10pts.]



[SCORING: [0...100], 100pts for a fully correct solution. The score cannot go below 0..]

14

In the following state graph, apply *LRTA** and report the list of visited states, including repetitions (e.g. $(0,1) \rightarrow (0,0) \rightarrow (0,1) \rightarrow ...$). The order of (untried) actions is $[up, right, down, left]$.

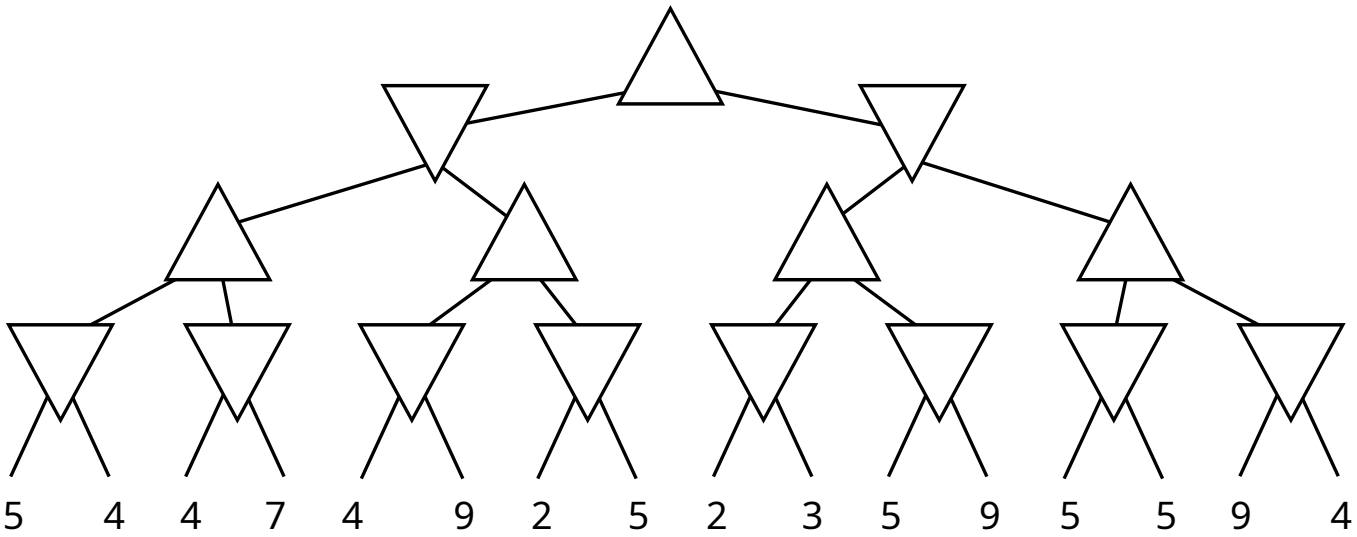


Start: $(1,1)$ - Goal: $(1,0)$

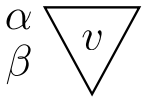
[SCORING: [0...100], 100pts for a fully correct solution, -10pts for each error in the resolution process. The score cannot go below 0..]

15

Use *Minimax with α, β-pruning* to propagate the utilities from the leaves to the root of the tree.



For each node report the values of α, β, as well as its returned value v **when the recursive calls ends**. Use the following format:



Additionally, clearly mark in the tree the pruned branches.

[SCORING: [0...100], 100pts for a fully correct solution, -20pts for each error in the resolution process. The score cannot go below 0..]