

Course “**Fundamentals of Artificial Intelligence**”
EXAM TEXT

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1

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 $O(b^s)$ steps to find a solution.
- (b) Depth-First Search with loop-prevention requires $O(b^s)$ memory to find a solution.
- (c) Breadth-First Search requires $O(b^m)$ memory to find a solution.
- (d) Breadth-First Search is optimal

[SCORING [0...100]:

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

]

2

Consider propositional logic (PL); let A, B, C, D, E, F, G 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:

$$\frac{\Gamma, (C \vee \neg D \vee \neg F), (\neg A \vee \neg C \vee \neg D)}{\Gamma, (\neg D \vee \neg A \vee \neg F)}$$

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

$$\frac{\Gamma, (F \vee \neg C \vee A), (\neg F \vee \neg A \vee D)}{\Gamma, (\neg C \vee D)}$$

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

$$\frac{\Gamma, (C), (F \vee \neg C \vee A)}{\Gamma, (C), (F \vee A)}$$

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

$$\frac{\Gamma, (F \vee A), (F \vee \neg C \vee A)}{\Gamma, (F \vee \neg C \vee A)}$$

[SCORING [0...100]:

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

]

3

In the following FOL formulas, let P, Q, R , and $>, \leq, <, \geq$ denote predicates,
 f, g, h, 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 $\forall x.((x > 2) \rightarrow (x > 1))$ is valid.
- (b) The FOL formula $(2 > 4)$ is unsatisfiable.
- (c) The FOL formula $(\forall x_2 \exists x_1. P(x_1, x_2)) \rightarrow (\exists x_1 \forall x_2. P(x_1, x_2))$ is valid.
- (d) The FOL formula $(\exists x_1. \neg P(x_1)) \leftrightarrow (\neg \forall x_1. P(x_1))$ is valid

[SCORING [0...100]:

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

]

4

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, Mop, Dib, Ate, Bek, Etu, Gop}

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

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

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

- Jud : Faeth \sqcap \exists haCidod.Panet
- Jud : Gapan \sqcap \forall haCidod.Moeth
- Mop : Moeth \sqcap (≥ 3)haCidod.Egier
- Jud : Faeth \sqcap (≥ 2)haCidod.Dotot

[SCORING [0...100]:

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

]

5

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

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

[SCORING [0...100]:

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

]

6

- (a) Describe as Pseudo-Code the Depth-Limited Search and Iterative-Deepening procedures.
- (b) calling b the branching factor and d 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.]

7

- (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.]

8

Given the following Sudoku scenario:

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

9

Consider the following CNF formula in PL:

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

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

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

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.]

10

An experienced doctor has to cope with an epidemic of covid19, where 30% of people of the area have been infected. She considers the following possible symptoms:

Symptom #1: fever;

Symptom #2: nausea;

Symptom #3: headache.

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

$P(\text{fever} \text{covid19})$	= 0.8
$P(\text{fever} \neg \text{covid19})$	= 0.1
$P(\text{nausea} \text{covid19})$	= 0.4
$P(\text{nausea} \neg \text{covid19})$	= 0.2
$P(\text{headache} \text{covid19})$	= 0.6
$P(\text{headache} \neg \text{covid19})$	= 0.3

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

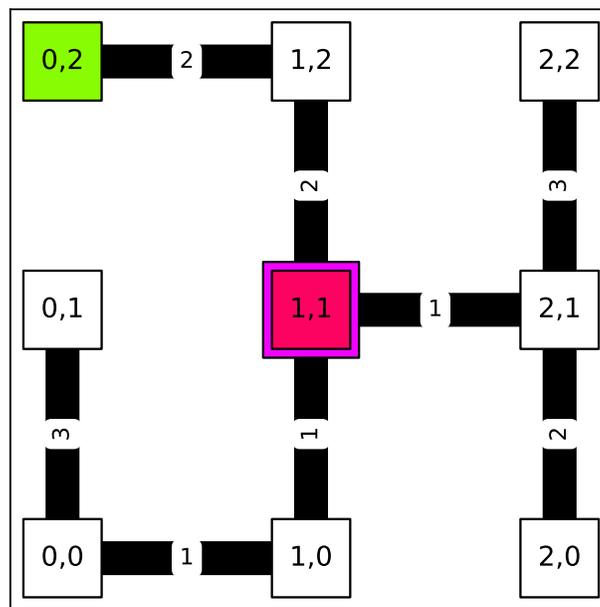
Notice: *the problem must be solved my using the Naive Bayes Model scenario. Any attempt to use any other technique will be considered incorrect.*

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

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

11

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

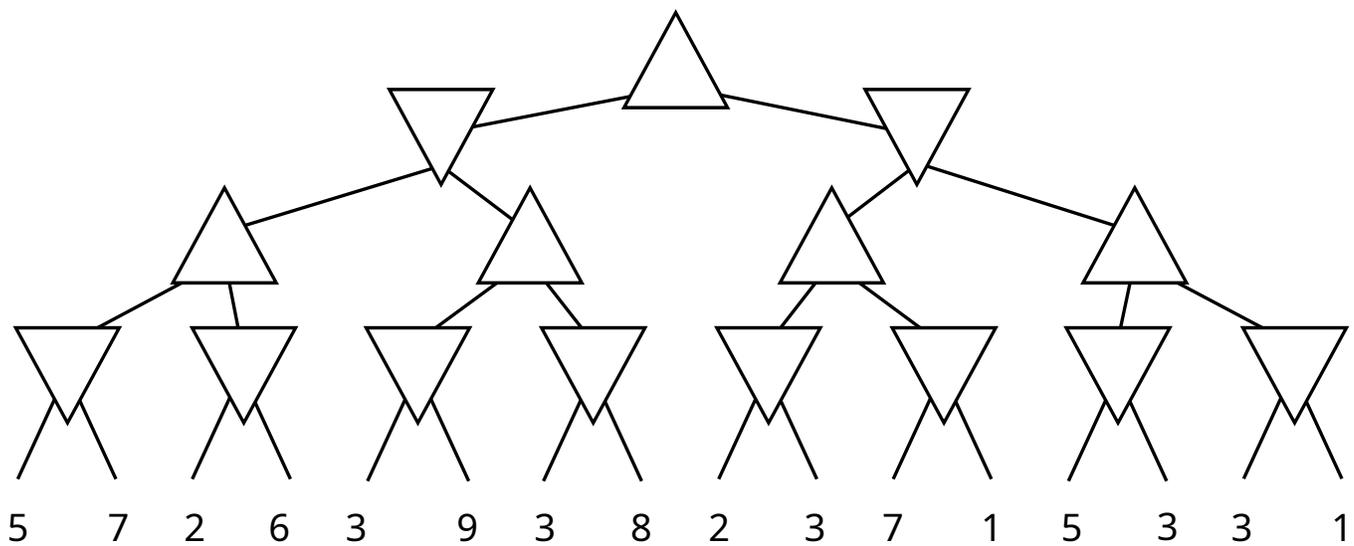


Start: $(1, 1)$ - Goal: $(0, 2)$

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

12

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:

$$\begin{array}{c} \alpha \\ \beta \end{array} \triangle v$$

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..]

13

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: $(0, 0)$.

For each step in the resolution process report (1) the current state; (2) the list of candidate next states.

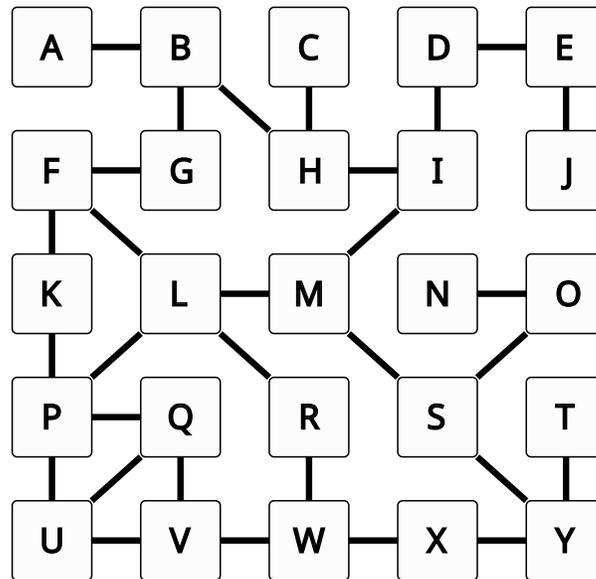
[SCORING: [0...100], 100pts for a fully correct solution, -20pts for each error in the resolution process. The score cannot go below 0..]

14

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.



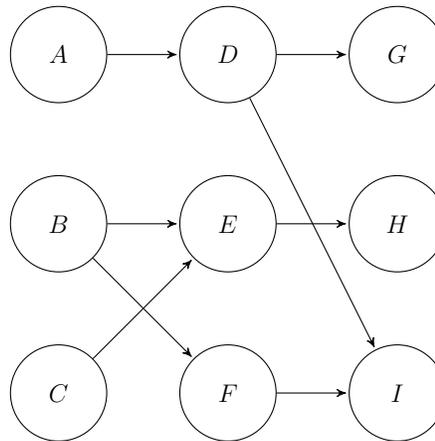
Start: M - Goal: J

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

15

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.]

R1:

R2:

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