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

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1

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

(a) Shortest-path search problems adopt an *atomic* representation of states.

(b) Propositional-logic problems adopt an *atomic* representation of states.

(c) CSP problems adopt a *factored* representation of states.

(d) First-order-logic problems adopt an *structured* representation of states.

[SCORING [0...100]:

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

]

2

Let

- $h(n)$ be a heuristic function representing the estimated cost from a node n to the solution,
- $h^*(n)$ represent the true cost from a node n to the solution,
- $c(n, a, n')$ represent the cost of passing from node n top node n' via action a.

For each of the following facts about heuristic search and A^*, say if it is true or false.

(a) $h(n)$ is admissible if and only if $h(n) = h^*(n)$.

(b) $h(n)$ is monotonic if and only if $h(n) \leq c(n, a, n') + h(n')$ for every successor n' of n generated by any action a

(c) if $h(n)$ is admissible, then $h(n)$ is monotonic, but the vice versa does not necessarily hold

(d) if $h(n)$ is monotonic, then $h(n)$ is admissible, but the vice versa does not necessarily hold

[SCORING [0...100]:

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

]

3

Consider (normal) modal logics. Let $\mathsf{IsIdle(Pump)}, \mathsf{IsOn(Light)}$ be possible facts, let Ed, Eve be agents and let $\mathbf{K}_{Ed}, \mathbf{K}_{Eve}$ denote the modal operators “Ed knows that...” and “Eve knows that...” respectively.
For each of the following facts, say if it is true or false.

(a) If $\mathbf{K}_{Ed}\mathsf{IsIdle(Pump)} \vee \mathbf{K}_{\mathsf{Ed}}\mathsf{IsOn(Light)}$holds, then $\mathbf{K}_{Ed}(\mathsf{IsIdle(Pump)} \vee \mathsf{IsOn(Light)})$ holds

(b) $\mathbf{K}_{Ed}\mathsf{IsIdle(Pump)} \wedge \mathbf{K}_{\mathsf{Ed}}\mathsf{IsOn(Light)}$ if and only if $\mathbf{K}_{Ed}(\mathsf{IsIdle(Pump)} \wedge \mathsf{IsOn(Light)})$ holds

(c) If $\mathbf{K}_{Eve}\mathsf{IsIdle(Pump)}$ and $\mathsf{IsIdle(Pump)} \rightarrow \mathsf{IsOn(Light)}$ hold, then $\mathbf{K}_{Eve}\mathsf{IsOn(Light)}$ holds

(d) If $\mathbf{K}_{Ed}\mathsf{IsIdle(Pump)}$ and $\mathbf{K}_{Ed}(\mathsf{IsIdle(Pump)} \rightarrow \mathbf{K}_{\mathsf{Eve}}\mathsf{IsOn(Light)})$ hold, then $\mathbf{K}_{Ed}\mathbf{K}_{Eve}\mathsf{IsOn(Light)})$ holds

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

- a set of primitive $\mathcal{ALCQ}$ concept names: {Pero, Mall, Fell, Doto, Eger}
- a set of $\mathcal{ALCQ}$ relation names: {haCilo}
- a set of $\mathcal{ALCQ}$ individual names: {Ja, Ju, Mo, Do, Ad, Bi, Ev, Gl}

$\mathcal{T}$-box $\mathcal{T}$

Pero		$\langle primitive\ concept \rangle$
Fell		$\langle primitive\ concept \rangle$
Mall		$\langle primitive\ concept \rangle$
Doto		$\langle primitive\ concept \rangle$
Eger		$\langle primitive\ concept \rangle$
Wonm	$\equiv$	Pero $\sqcap$ Fell
Mnam	$\equiv$	Pero $\sqcap$ Mall
Moet	$\equiv$	Wonm $\sqcap \exists$haCilo.Pero
Faet	$\equiv$	Mnam $\sqcap \exists$haCilo.Pero
Part	$\equiv$	Pero $\sqcap$ haCilo.Pero
Gamr	$\equiv$	Moet $\sqcap$ haCilo.Part
Gafr	$\equiv$	Faet $\sqcap$ haCilo.Part
Gpar	$\equiv$	Part $\sqcap$ haCilo.Part

$\mathcal{A}$-box $\mathcal{A}$

Mo : Wonm; Ev : Wonm; Gl : Wonm; Ja : Wonm;

Ju : Mnam; Ad : Mnam; Bi : Mnam; Do : Mnam;

Ad : Doto; Mo : Doto

Ev : Eger; Gl : Eger; Ja : Eger

⟨Ju, Mo⟩ : haCilo; ⟨Ju, Ad⟩ : haCilo;
⟨Ju, Ev⟩ : haCilo;

⟨Mo, Gl⟩ : haCilo; ⟨Mo, Bi⟩ : haCilo;
⟨Mo, Do⟩ : haCilo; ⟨Mo, Ja⟩ : haCilo;

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

(*a*) Ju : Gafr $\sqcap \exists$haCilo.Moet
(*b*) Ju : Part $\sqcap (\leq 1)$haCilo.Doto
(*c*) Ju : Faet $\sqcap \forall$haCilo.(Doto $\sqcup$ Eger)
(*d*) Mo : Part $\sqcap (\geq 2)$haCilo.Mall

[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 $\mathbf{P}(A|B,C) = \mathbf{P}(A|C)$

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

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

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

[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 WalkSAT local-search SAT procedure.

(b) If the procedure fails to find a satisfying assignments, this means that:

1 the input formula is unsatisfiable

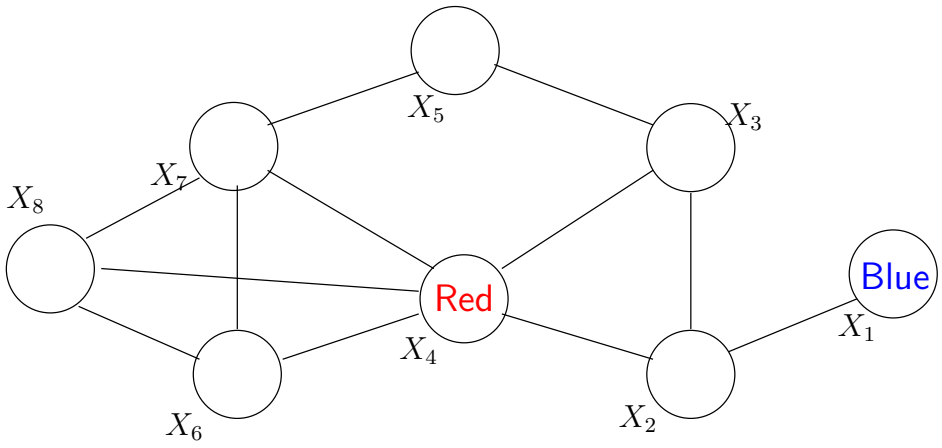
2 we can conclude nothing about the satisfiablity of the input formula

(Say if 1. or 2.)

[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

Consider the following constraint graph of a map coloring problem, with domain $D \stackrel{\text{def}}{=} \{\text{Red}, \text{Green}, \text{Blue}\}$, and consider the partial value assignment induced by the following unary constraints:
$\{X_1 = \text{Blue}, X_4 = \text{Red}\}$ (see figure).



(i) Describe the domain of the unassigned nodes after applying the forward-checking algorithm to the current status of the graph.

(ii) After running forward-checking, is the resulting status of the problem ARC-consistent?

(iii) Can forward-checking alone detect any inconsistency in this graph? In either case explain why.

Notation: to represent the current domain of a node X_i, substitute with a blank “ ” any value in $\{\text{Red}, \text{Green}, \text{Blue}\}$ which cannot be assigned. (Ex: in current graph: $X_1 : \{\ ,\ ,\ , \text{Blue}\}$)

[SCORING: [0...100], 50 pts for correct answer to question (i), 25pts each for correct answer to (ii) and (iii). No penalties for wrong answers..]

8

Consider the following propositional formula φ:

$$(\quad A_5 \leftrightarrow \quad A_6) \wedge \neg((\quad A_3 \vee \neg A_2) \wedge (\neg A_1 \vee \quad A_4))$$

1. Using the “classic” CNF conversion, produce the CNF formula $CNF(\varphi)$.
2. For each of the following sentences, only one is true. Say which one.

   (i) φ and $CNF(\varphi)$ are equivalent.
   (ii) φ and $CNF(\varphi)$ are equi-satisfiable, but not necessarily equivalent.
   (iii) There is no relation between the satisfiablity of φ and that of $CNF(\varphi)$.

[SCORING: [0...100], 75pts for correct answer 1, 25pts for correct answer 2. No penalties for wrong answers..]

9

Consider the following Horn formula in PL:

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

Using the simple polynomial procedure for Horn formulas,

(a) decide if the formula is satisfiable or not

(b) if satisfiable, return the satisfying total truth assignment;
if unsatisfiable, return the falsified clause.

Note: Solving the problem by using any other procedure will be considered incorrect.

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

10

Let $P()$, $Q()$, $R()$, $S()$, $T()$, $U()$ denote predicates, a, b, c, d, e denote constants.
Consider the following set of clauses:

$$P(a) \vee Q(c) \vee R(b)$$
$$\neg U(a) \vee R(b)$$
$$\neg P(a) \vee R(b) \vee T(e)$$
$$\neg Q(c) \vee T(e) \vee \neg S(d)$$
$$\neg R(b) \vee U(a)$$
$$S(d) \vee T(e)$$
$$\neg T(e) \vee R(b)$$
$$\neg R(b)$$

Build a refutation using the Hyper-Resolution strategy.

[SCORING: [0...100], 100 pts for correct answer. 0 points if you use any resolution strategy which is not hyper-resolution. No penalties for wrong answers..]

11

(a) Describe as Pseudo-Code the Uniform-Cost Search (UCS) stategy (graph version).

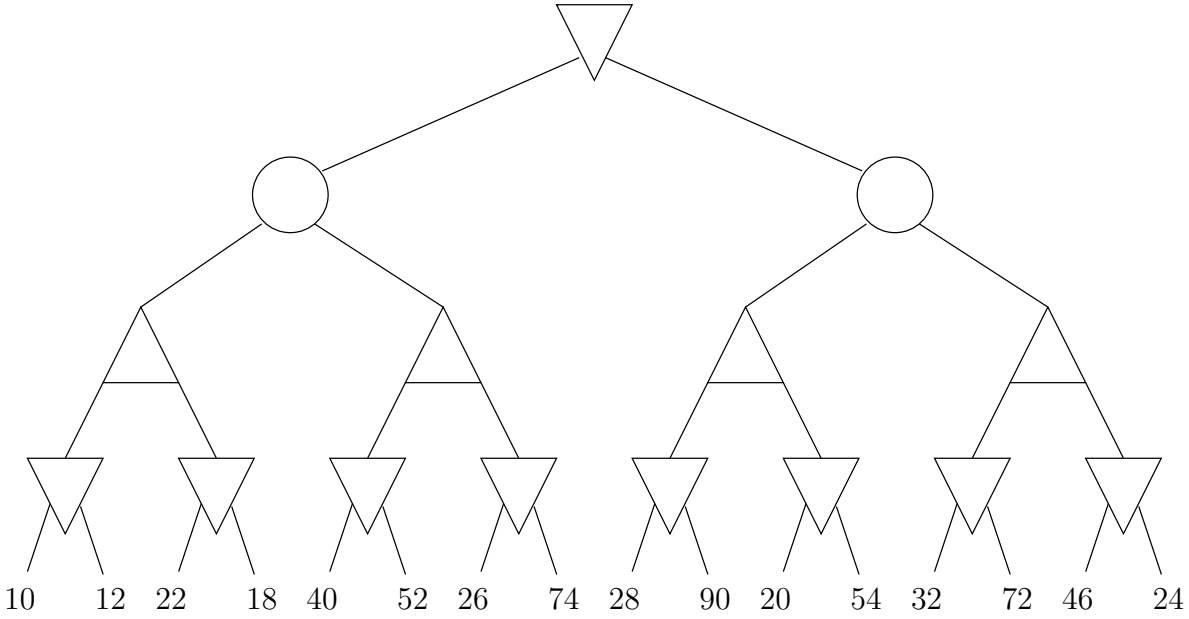
(b) When is the goal test applied to a node? (Say if 1. or 2.)

1 when the node is selected for expansion

2 when the node is first generated

[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.]

12



Use *ExpectiMinimax* to propagate the expected utilities from the leaves to the root of the tree. Chance nodes assign uniform probabilities to their children.

[SCORING: [0...100], 100pts for a fully correct solution, -20pts 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	1
B	2
C	3
D	2
E	2
F	1
G	3
H	2
I	3
J	2
K	3
L	3

$A \prec E \quad A \prec F$
$B \prec E \quad B \prec F \quad B \prec H$
$C \prec E \quad C \prec G$
$D \prec F \quad D \prec G \quad D \prec H$
$E \prec I \quad E \prec J \quad E \prec K$
$F \prec I \quad F \prec J$
$G \prec I \quad G \prec K \quad G \prec L$
$H \prec J \quad H \prec K$

Using the Critical Path method:

- Compute the earliest / latest possible start time (ES/LS) for each action.
- Indicate which actions are in a critical path and the minimum makespan.

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

14

Assume the following facts are known from medicine literature: [1]

- 4 persons over 1000 suffer of flu
- 5 % of persons have high_temperature
- one person with flu has high_temperature with probability 0.8

Given that a person has high_temperature, compute the probability of having flu.

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

[1] These data are pure fantasy and have no correspondence with real-world medicine.

15

An experienced doctor has to cope with an epidemic of dengue, where 20% of people of the area have been infected. She considers the following possible symptoms:

Symptom #1: high temperature;
Symptom #2: headache;
Symptom #3: vomit.

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: [2]

$P(high\ temperature \mid\ dengue)$	$= 0.7$
$P(high\ temperature \mid \neg dengue)$	$= 0.1$
$P(headache \mid\ dengue)$	$= 0.3$
$P(headache \mid \neg dengue)$	$= 0.2$
$P(vomit \mid\ dengue)$	$= 0.6$
$P(vomit \mid \neg dengue)$	$= 0.2$

She is informed that one patient has headache and vomit but not high temperature. Compute the probability that such patient has contracted dengue.

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

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