CSCE420: Introduction to Artificial Intelligence
Prior Final Exam Questions

The following questions are all questions from prior examinations (finals and midterms).

Important: Your exam assumes that you will have prepared **6 pages** of notes. These can be US-letter, double-sided, typeset or written—to be brought with you on Mar 6th. These practice questions can give you a sense of what it might be useful to include in your notes.

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Question 1. Classical Planning: Execution

The following is PDDL description of a blocks-world problem.

$Init(On(A, Table) \land On(B, Table) \land On(C, A)$
$\quad \land Block(A) \land Block(B) \land Block(C) \land Clear(B) \land Clear(C)$
$Goal(On(A, B) \land On(B, C))$
$Action(Move(b, x, y),$
$\quad$ PRECOND: $On(b, x) \land Clear(b) \land Clear(y) \land Block(b) \land Block(y)$
$\quad \land (b \neq x) \land (b \neq y) \land (x \neq y),$
$\quad$ EFFECT: $On(b, y) \land Clear(x) \land \neg On(b, x) \land \neg Clear(y))$
$Action(MoveToTable(b, x),$
$\quad$ PRECOND: $On(b, x) \land Clear(b) \land Block(b) \land (b \neq x),$
$\quad$ EFFECT: $On(b, Table) \land Clear(x) \land \neg On(b, x))$

1.1 Write down all the actions that are applicable from the initial state. (2 pts)

$Move(B, Table, C), \quad Move(C, A, B),$
$MoveToTable(B, Table), \quad MoveToTable(C, A)$

1.2 Show all the steps involved in updating the state when action $Move(C, A, B)$ is executed from the initial state. Show the delete list and add list operations separately. (6 pts)

$s = \{On(A, Table) \land On(B, Table) \land On(C, A) \land Block(A) \land Block(B) \land Block(C) \land Clear(B) \land Clear(C)\}$

$s' = s - Del(\cdot) = s - \{On(C, A), Clear(B)\} = \{On(A, Table) \land On(B, Table) \land Block(A) \land Block(B) \land Block(C) \land Clear(C)\}$

$s'' = s' \cup Add(\cdot) = s' \cup \{On(C, B), Clear(A)\} = \{On(A, Table) \land On(B, Table) \land On(C, B) \land Block(A) \land Block(B) \land Block(C) \land Clear(A) \land Clear(C)\}$

Question 2. Classical Planning: Definitions

1. Describe the relationship between planning and search by completing the following description:

(2 pts)

Complete final the sentence are completely and informatively as you can:

Like search, planning involves problem-solving. Planning can be implemented with search-based methods, but planning systems utilize explicit propositional or relational representations of states and actions. In constrast, search typically considers atomic representations of search states.

2. Russell & Norvig state (second paragraph on page 367) that $\neg Poor$ is not permitted as a fluent in a state because it is a negation. But several places (bottom of page 367, several in Figure 10.1) we see negations. Explain.

(2 pts)

The ¬ symbol has a special meaning in classical planning. It only occurs in EFFECT lists and denotes an element within the delete list.

3. How do propositional logical inference-based agents and PDDL planning-based agents compare? Describe their differences in terms of: level of expressiveness (first-order logic vs. PDDL) , theoretical worst-case performance, and practical performance.

(5 pts)

Logic as we have examined is strictly more expressive than that permitted by the PDDL planners.
Both have exponential worst-case performance (one is in NP, the other is semi-undecidable, but NP-Hard even for refutation completeness). [Take any solution with Logic $\geq$ PDDL]
Finding a sub-optimal plan using PDDL is usually faster (it is in P), so it has better practical performance.

Question 3: Wolf, goat, and cabbage in PDDL

Old MacDonald—the very same one who had a farm—went to market and bought a wolf, a goat, and a cabbage. On his way home, he came to the bank of a river and found a boat. It was a small rowing boat, so he could cross carrying only himself and a single one of his purchases: either the wolf, the goat, or the cabbage.

The trouble is that wolves devour goats, if left together unattended. Similarly, the goat would eat the cabbage, if left together unattended. Yet, MacDonald managed to carry himself and his purchases to the far bank of the river, without the loss of any purchases.

Write down a PDDL description of MacDonald's conundrum, so that a planner could find a solution. You may use either the abstract style of description used in the textbook, or the more concrete form in your programming assignment.

Many solutions are possible, here's a particularly concise one in PDDL (based on Peter Lightbody's solution). A more obvious one would be a variation of the cargo domain.

```
(:domain boat)
; only needs two objects, namely representing either bank side of the river,
(:objects  w e) ; [w]est and [e]ast
(:INIT
    ; wolf, goat, cabbage, boat are all on the east side to start with
    (config e e e e)

    ; represent all valid states  these two are the special case,
    ; representing that wolf and cabbage are safe together even
    ; if the boat is away
    (valid w e w e) (valid e w e w)

    ; these are all cases where two entities are always safe as long as
    ; the boat is with them. In other words, a single entity on the other
    ; side is also always safe for west side
    (valid w w w w) (valid w w e w) (valid w e w w) (valid e w w w)
    ; for east side
    (valid e e e e) (valid e e w e) (valid e w e e) (valid w e e e)
    ; these are all valid states that are ever allowed
)
(:goal (AND
        ; wolf, goat, cabbage together on the west bank
        (config w w w w)
    )
)
```

Question 4: First-Order Logic Modeling (9 points)

Here is a scenario we studied in class, when discussing propositional logic:

"Jack is looking at Anne, but Anne is looking at George.
Jack is married, but George is not."

We then asked the following question:

"Is a married person looking at an unmarried person?"

1) Using the predicates **Person**, **Married**, **LookingAt**, express the facts in the domain as a single sentence in first-order logic.

$\textbf{Person}(Jack) \wedge \textbf{Person}(Anne) \wedge \textbf{Person}(George) \wedge$
$\textbf{Married}(Jack) \wedge \neg\textbf{Married}(George) \wedge$
$\textbf{LookingAt}(Jack, Anne) \wedge \textbf{LookingAt}(Anne, George)$

2) Express the question in first-order logic.

$\exists m, u\ \textbf{Person}(m) \wedge \textbf{Person}(u) \wedge \textbf{Married}(m) \wedge \neg\textbf{Married}(u) \wedge \textbf{LookingAt}(m, q)$

3) If the correct answer to the first part of the question is A_1 and the second part is A_2, then does $A_1 \models A_2$?

Yes.

Question 4: Proof in Propositional Logic (9 points)

On the Isle of Knights and Knaves: Knights always tell the truth, and Knaves always lie. However, it is not immediately obvious who is a Knight and who is a Knave.

You encounter Albert, Betty, and Carla, who are each either Knights or Knaves.

Albert says: *"Betty is a Knight, but Carla is a Knave."*
Betty says: *"Two of us are Knights."*
Carla says: *"Albert and I are both Knights."*

Prove that Carla is a Knave.
(Ensure that you describe each step and clearly label the rules you applied.)

First, formalize the known facts in Propositional Logic:

(i) Albert asserts "$B \wedge \neg C$":
$$(A \implies B \wedge \neg C) \wedge (\neg A \implies \neg(B \wedge \neg C))$$
(ii) Betty asserts says "$(A \wedge B) \vee (A \wedge C) \vee (B \wedge C) =: P$":
$$(B \implies P) \wedge (\neg B \implies \neg P)$$
(iii) Carla says "$A \wedge C$":
$$(C \implies A \wedge C) \wedge (\neg C \implies \neg(A \wedge C))$$

Now to prove that Carla is a Knave:

To prove $KB \models \neg C$

Proceed by contradiction, so assume $KB \models C$

(D1)	$(C \implies A \wedge C)$	[(iii) with And Elimination]
(D2)	$A \wedge C$	[D1 with Modus Ponens]
(D3)	A	[D2 with And Elimination]
(D4)	$(A \implies B \wedge \neg C)$	[(i) with And Elimination]
(D5)	$B \wedge \neg C$	[D3, D4 with Modus Ponens]
(D6)	$\neg C$	[D5 with And Elimination]

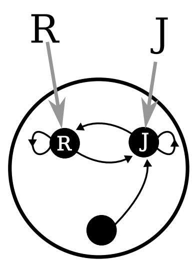
Hence contradiciton reached.

Question 5: Short Questions (9 points)

5.1 True or False: "It is always possible to prove that a sentence in propositional logic is entailed or not entailed by a knowledge base." Give a brief justification. (2 pts)

True: there is a finite domain, so you could just check the sentence in all the models consistent with the KB.

5.2 Someone was asked to draw a diagram showing some member of the set of all models for a language with two constant symbols, R and J, and one binary relation, under database semantics. If the diagram below is the result, their depiction is not a correct interpretation. Explain why not. (2 pts)



Database semantics requires domain closure. This is violated because there is an element in the domain which is unnamed (bottom dot).

5.3 True or False: The expression "$\neg P \vee \neg Q$" is a Horn clause. Briefly explain why. (2 pts)

True. $\neg P \vee \neg Q$ can be written as $\text{False} \Leftarrow P \wedge Q$. This is a goal clause.

5.4 Explain the intuition behind the minimum-remaining-values heuristic in a CSP search. (3 pts)

We want to detect inevitable failure as soon as possible. The variable that is most likely to cause failure in a branch is assigned first $\implies$ most constrained variable prunes the tree sooner.

Question 6. True or False

Answer True or False and provide an illustratory example or explanation.

1. Backus-Naur Form (BNF) is commonly used to describe the semantics of a formal language. (2 pts)

False: it describes the syntax, e.g., propositional logic, FOL.

2. Abduction is a form of deductive inference. (2 pts)

False: it is a form of contingent inference, in which a precondition is inferred from the consequent.

3. First-order logic and propositional logic are primarily distinguished by their epistemological commitments. (2 pts)

False: both have truth, falsity, or a state of unknowing about facts.

4. "There is a tree which is taller than any human" is a good translation of $\exists t\, Tree(t) \Rightarrow [\exists h\, Human(h) \wedge Height(t) > Height(h)]$ (2 pts)

True: Using a step-function the output would only be 0 or 1 – so they can be set-up to output descrete values.

5. Clause $(A \Leftrightarrow B) \wedge (\neg A \vee B)$ is valid. (2 pts)

False: (A = false, B = false) does not cause the clause to be true.

6. The Peano axioms define the positive integers. (2 pts)

False: They include the zero element.

7. The statement of the contrapositive can be expressed in first-order logic, i.e., "For all predicates, $P(x) \Rightarrow Q(x)$, is equivalent to $\neg Q(x) \Rightarrow \neg P(x)$." (2 pts)

False: Because this is a statement about predicates themselves, it is a second-order expression.

In addition to these questions, we have worked two detailed examples in class. The first is resolution-based proof in FOL, the second is ID3 for decision tree induction. Though no prior questions appear for these, both will have questions on the final exam. Practice those!