Midterm Exam

600.464/664 Artificial Intelligence
Spring 2024

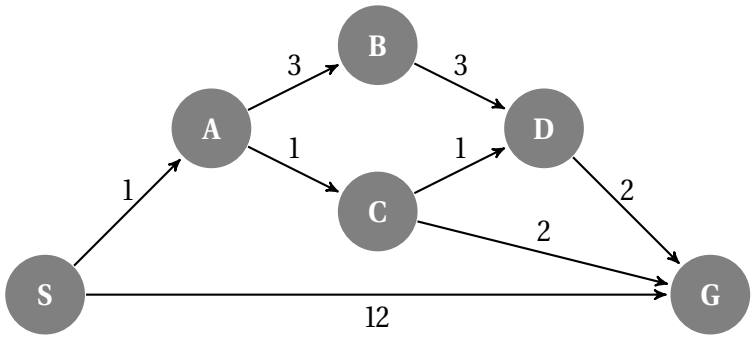
Name:

Instructions

- Please be sure to write your name in the space above!
- Please be sure to read through the entire exam before you start, and be mindful of the time. If one question is taking too long, it may be worth moving on and coming back to the problem question(s) after the rest of the exam is complete.
- Remember that you are only allowed one sheet (both sides) of notes, everything else besides that and the test itself must be off of your workspace.
- Please show ALL relevant work for your answers and provide explanations when prompted. Failure to do either will result in loss of credit.

Informed Search *10 points*

Consider the search space below, where **S** is the start node and **G** satisfies the goal test. Arcs are labeled with the cost of traversing them and the heuristic cost to the goal is reported inside nodes (so lower scores are better).



Answer the following questions about the search problem shown above. Break any ties alphabetically. For the questions that ask for a path, please give your answers in the form 'S-A-D-G.'

1. (3 points) What path would breadth-first search return for this search problem?

   S-G

2. (3 points) What path would depth-first search return for this search problem?

   S-A-B-D-G

3. (4 points) Consider the heuristics for this problem shown in the table below.

State	h_1	h_2
S	5	4
A	3	2
B	6	6
C	2	1
D	3	3
G	0	0

   Answer yes or no:

   - Is h_1 admissible?

     No

   - Is h_2 admissible?

     No

An admissible heuristic must underestimate or be equal to the true cost. h_1 overestimates the cost S→G as 5 when it is 4, so it is inadmissible. h_2 overestimates the cost B→G as 6 when it is 5, so it is inadmissible.

Prepositional Logic *10 points*

4. Simplify the following sentences, e.g., eliminate any term that has no impact on the truth of the sentence

   (a) (2 points) $\neg$ (A $\vee$ B) $\wedge$ A

   $\neg A \wedge \neg B \wedge A = False$

   (b) (2 points) (A $\wedge$ B) $\vee \neg$ B

   $(A \vee \neg B) \wedge (B \vee \neg B) =$
   $(A \vee \neg B) \wedge True$
   $A \vee \neg B$

   (c) (3 points) A $\vee$ (A $\implies$ B)

   $A \vee (\neg A \vee B) =$
   $A \vee \neg A \vee B =$
   $True$

   (d) (3 points) ((A $\wedge$ B) $\implies$ B) $\implies$ C

   $((\neg (A \wedge B) \vee B) \implies C =$
   $(\neg A \vee \neg B \vee B) \implies C =$
   $True \implies C =$
   $\neg True \vee C$
   C

First Order Logic *15 points*

5. (5 points) Convert the following sentences into first-order predicate calculus logic:

   A female bird lays eggs.

   $\forall$ x: Bird(x) $\wedge$ Female(x) $\Longrightarrow$ LaysEggs(x)

   If it has feathers, it is a bird.

   $\forall$ x: HasFeathers(x) $\Longrightarrow$ Bird(x)

   All ravens have feathers.

   $\forall$ x: Raven(x) $\Longrightarrow$ HasFeathers(x)

   Shaddow is a raven.

   Raven(Shaddow)

   Shaddow is female.

   Female(Shaddow)

6. (5 points) Convert all rules to Conjunctive Normal Form (CNF). You do not need to restate rules that are already in CNF.

   $\neg$ *Bird(x)* $\vee$ $\neg$ *Female(x)* $\vee$ *LaysEggs(x)*
   $\neg$ *HasFeathers(x)* $\vee$ *Bird(x)*
   $\neg$ *Raven(x)* $\vee$ *HasFeathers(x)*
   Raven(Shaddow)
   Female(Shaddow)

7. (5 points) Carry out a resolution proof of the statement: *Shaddow lays eggs.*

$$\frac{\neg\ \mathit{LaysEggs(Shaddow)} \qquad \neg\ \mathit{Bird(x)} \vee \neg\ \mathit{Female(x)} \vee \mathit{LaysEggs(x)}}{\neg\ \mathit{Bird(Shaddow)} \vee \neg\ \mathit{Female(Shaddow)}}$$

$$\frac{\neg\ \mathit{Bird(Shaddow)} \vee \neg\ \mathit{Female(Shaddow)} \qquad \mathit{Female(Shaddow)}}{\neg\ \mathit{Bird(Shaddow)}}$$

$$\frac{\neg\ \mathit{Animal(Shaddow)} \vee \neg\ \mathit{Bird(Shaddow)} \qquad \mathit{Raven(Shaddow)}}{\neg\ \mathit{Bird(Shaddow)} \vee \mathit{Raven(Shaddow)}}$$

$$\frac{\neg\ \mathit{Bird(Shaddow)} \vee \mathit{Raven(Shaddow)} \qquad \neg\ \mathit{Ravens(x)} \vee \mathit{HasFeathers(x)}}{\neg\ \mathit{Bird(Shaddow)} \vee \mathit{HasFeathers(Shaddow)}}$$

$$\frac{\neg\ \mathit{Bird(Shaddow)} \vee \mathit{HasFeathers(Shaddow)} \qquad \neg\ \mathit{HasFeathers(x)} \vee \mathit{Bird(x)}}{\mathit{Fail}}$$

Constraint Satisfaction *15 points*

You are planning a dinner party and need to assign seating arrangements for 6 guests: Alice, Bob, Carol, David, Eve, and Frank. They sit on a single round table in a circle, with everybody have two neighbors. However, there are certain constraints you need to consider:

(a) Alice cannot sit next to Bob.

(b) Bob cannot sit next to Carol.

(c) Carol cannot sit next to David or Eve.

(d) Frank cannot sit next to Alice or Bob.

Assume that Alice sits in chair 1, the other chairs are numbered 2–6.

8. (8 points) Carry out backtracking search. Explore the search space in the alphabetic order of the guest names, with preference for a lower-numbered seats, if there are multiple valid options.

A-1 → (B-2) B-3 → C-5 → D-2 → E-fail
→ C-6 → D-2 → E-4 → F-5

9. (7 points) Now, use the minimum remaining values (MRV) heuristic and forward checking. Fill in the following table. In case of ties follow alphabetical order.

Step		Alice	Bob	Carol	David	Eve	Frank
	assigned value	1					
	remaining values	-	3–6	2–6	2–6	2–6	2–5
1	assigned value						
	remaining values						
2	assigned value						
	remaining values						
3	assigned value						
	remaining values						
4	assigned value						
	remaining values						
5	assigned value						
	remaining values						
6	assigned value						

(1) / 3-6 / 2-6 / 2-6 / 2-6 / 2-5
(1) / (3) / 5-6 / 2,4-6 / 2,4-6 / 5
(1) / (3) / 6 / 2,4,6 / 2,4,6 / (5)
(1) / (3) / (6) / 2,4 / 2,4 / (5)
(1) / (3) / (6) / (2) / 4 / (5)