Midterm Exam

600.664 Artificial Intelligence
Spring 2025

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.

Cognitive Psychology *10 points*

In the lectures we discussed two modes of thinking: System 1 (which represents fast, intuitive understanding) and System 2 (which represents slow, conscience reasoning).

1. (3 points) Give an example of a human mental task that is performed by System 1.

   Recognizing human emotion, etc.

2. (3 points) Give an example of a human mental task that is performed by System 2.

   Working through a math problem, etc.

3. (4 points) The logic paradigm we discussed in class matches the notion of System 2 thinking. When a human solves a mathematical puzzle, such as computing angles or lengths in a triangle, give some examples why this still requires System 1 thinking.

   Recognizing the triangle, recalling the method to solve the problem, basic math operations like 4+2.

Informed Search *20 points*

Consider the following problem in a grid-based world. You are given a 4x4 grid where the agent starts at the position (0, 1) and needs to reach the goal at (3, 3). The grid has some obstacles through which the agent cannot pass. You must use the A* search algorithm to find the shortest path from the start to the goal.

The grid is as follows, where "S" is the start, "G" is the goal, "X" represents an obstacle, and "·" represents an empty space:

·	S	·	·
·	X	·	X
·	·	·	·
X	·	X	G

Assume that the movement is allowed in the four cardinal directions (up, down, left, right), and the cost of moving from one cell to an adjacent one is always 1.

4. (5 points) Heuristic Function: Define a suitable heuristic function for the A* algorithm to use in this scenario. Explain why your heuristic is admissible.

   Manhattan distance to Goal. Admissible because it never overestimates the true cost to reach the goal; it assumes straight-line movement without obstacles, so it represents a lower bound of the actual cost to reach the goal.

5. (10 points) A Search*: Using your defined heuristic, perform the A* search to find the optimal path from the start to the goal. Show your work by describing the steps the algorithm would take by drawing the search tree, including the nodes explored, their accumulated and heuristic costs, and the order in which they are expanded.

```
(0,1) 0+5 = 5
* (0,0) 1+6 = 7
* (0,2) 1+4 = 5
* * (0,1) 2+6 = 8
* * (0,3) 2+3 = 5
* * (1,2) 2+3 = 5
* * * (0,2) 3+4 = 7
* * * (2,2) 3+2 = 5
* * * * (1,2) 4+3 = 7
* * * * (2,1) 4+3 = 7
* * * * (2,3) 4+1 = 5
* * * * * (2,2) 5+2 = 7
* * * * * (3,3) 5+0 -- GOAL
```

6. (5 points) Analysis: Explain how the heuristic affects the search process. Compare it to an uninformed search strategy (e.g., breadth-first search) in terms of the number of nodes expanded and the efficiency of finding the goal (no actual numbers needed).

   BFS explores all possible paths level by level, which could expand many more nodes because it does not consider the proximity to the goal. It will eventually find the goal but in a much less efficient manner.

First Order Logic *20 points*

Write first-order logic representations of the following sentences.

7. (2 points) All humans are mortal.

   $\forall x(Human(x) \rightarrow Mortal(x))$

8. (2 points) Socrates is a human.

   $Human(Socrates)$

9. (2 points) All mortals eventually die.

   $\forall x(Mortal(x) \rightarrow EventuallyDie(x))$

10. (2 points) Socrates will eventually die.

    $EventuallyDie(Socrates)$

11. (4 points) Convert all rules to Conjunctive Normal Form (CNF). You do not need to restate rules that are already in CNF.

    $\neg Human(x) \lor Mortal(x)$
    $\neg Mortal(x) \lor EventuallyDie(x)$

12. (8 points) Carry out a resolution proof of the last sentence from the first three sentences.

    Resolve $\neg Human(Socrates) \lor Mortal(Socrates)$ ***and*** $Human(Socrates)$
    which gives $Mortal(Socrates)$
    Resolve $Mortal(Socrates)$ ***and*** $\neg Mortal(Socrates) \lor EventuallyDie(Socrates)$
    which gives $EventuallyDie(Socrates)$

Constraint Satisfaction *10 points*

We are tasked with assigning rooms to 5 guests, ensuring that no two guests are assigned the same room, and each guest is assigned a room they prefer.

The domain for each variable is the set of rooms each guest is willing to stay in:

$$\text{Domain(Alice)} = \{\text{Room } 1, \text{Room } 3, \text{Room } 4\}$$

$$\text{Domain(Bob)} = \{\text{Room } 2, \text{Room } 3, \text{Room } 5\}$$

$$\text{Domain(Charlie)} = \{\text{Room } 1, \text{Room } 2\}$$

$$\text{Domain(David)} = \{\text{Room } 1, \text{Room } 2, \text{Room } 4, \text{Room } 5\}$$

$$\text{Domain(Eve)} = \{\text{Room } 1, \text{Room } 3, \text{Room } 5\}$$

Each guest must be assigned to exactly one room. No two guests can be assigned to the same room. The goal is to assign a room to each guest while satisfying all the constraints.

13. (10 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*	*Charlie*	*David*	*Eve*
0	*Room 1, 3, 4*	*Room 2, 3, 5*	*Room 1, 2*	*Room 1, 2, 4, 5*	*Room 1, 3, 5*
1	*Room 3, 4*	*Room 2, 3, 5*	**Room 1**	*Room 2, 4, 5*	*Room 3, 5*
2	**Room 3**	*Room 2, 5*	*Room 1*	*Room 2, 4, 5*	*Room 5*
3	*Room 3*	*Room 2*	*Room 1*	*Room 2, 4*	**Room 5**
4	*Room 3*	**Room 2**	*Room 1*	*Room 4*	*Room 5*
5	*Room 3*	*Room 2*	*Room 1*	**Room 4**	*Room 5*