**Due: 03/18/2025 23:59**

# Foundations of Artificial Intelligence: Homework 1

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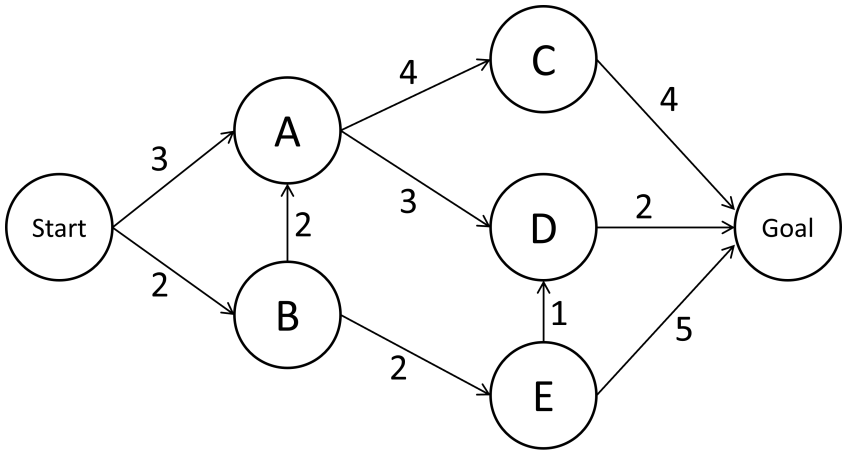
- Please label each question with its corresponding number and also indicate the answer clearly.
- Any form of cheating, lying, or plagiarism is strictly prohibited. Violations will result in a zero score and failure of the course.
- You may consult ChatGPT, books, notes, and Internet resources, but you must not copy directly from them.
- Ensure that your uploaded file is clearly readable. If using a camera to scan, check the resolution for clarity.
- If you have any questions about the problems, please ask in the NTUCOOL discussion panel first.
- Version 2 (2025.03.06): revised parts are highlighted in red.
- Version 3 (2025.03.10): revised parts are highlighted in blue.

**Problem 1** (10 points)




Write down the **order of state expansion** and the **final path** returned by each of the search algorithms below. You can assume ties are resolved alphabetically. Note that each node needs to be expanded only once.

**(1)** Depth-first search. (Please use a stack and push the elements onto it in alphabetical order.)

**(2)** Breadth-first search. (Please use a queue and push the elements onto it in alphabetical order.)

**(3)** Uniform cost search.

**(4)** Greedy search with the heuristic $h_1$ as follows.

| State ($n$) | A | B | C | D | E |
|---|---|---|---|---|---|
| $h_1(n)$ | 6 | 6 | 4 | 2 | 3 |

**(5)** $A^*$ search with the same heuristic $h_1$.

**(6)** Is the heuristic function $h_1$ admissible? Does the $A^*$ search algorithm return the optimal solution? Briefly justify your answer.

**(7)** Is the heuristic function $h_1$ consistent? Briefly justify your answer.

**(8)** Given that $h_2(n) = 0.5 \times [h_1(n) + h^*(n)]$, where $h^*(n)$ is the actual cost from $n$ to the goal, is $h_2$ admissible? Why or why not?

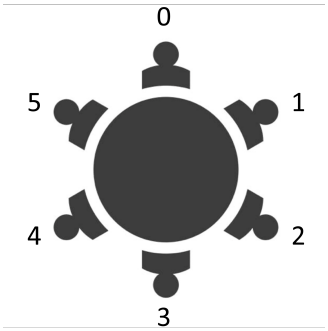
**(9)** Suppose that you are given an inadmissible heuristic $h_3(n)$. If you can modify the heuristic value for **only one** node, which node would you choose, and what value would you assign to make the heuristic admissible?

| State ($n$) | A | B | C | D | E |
|---|---|---|---|---|---|
| $h_3(n)$ | 8 | 5 | 2 | 2 | 2 |

**(10)** Following (9), after making the modification, is the heuristic consistent? Briefly explain the reason.

**Problem 2** (10 points)

Six people, A, B, C, D, E, and F, are seated around a circular table with six numbered seats (0 to 5) arranged in a clockwise order. Each person must be assigned to exactly one seat, and no two people can sit in the same seat. The seating arrangement must satisfy the following constraints:




1. D must sit at seat 0.
2. B is seated as the second person to the right of A. (Ex. if A sit at 3, B must sit at 1.)
3. D and F cannot be adjacent.
4. D cannot be directly opposite to E.
5. F is seated as the second person to the left of C.

**(1)** Formulate this as a CSP problem, considering the variables A, B, C, D, E, and F, where the domain is {0,1,2,3,4,5}. Clearly state all constraints.

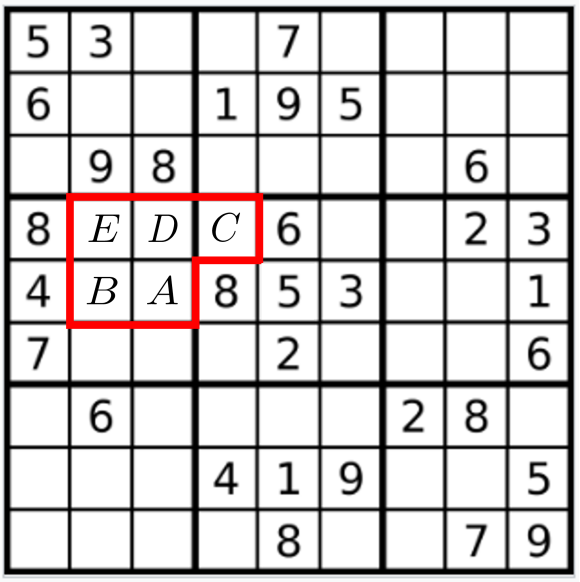
**(2)** Solve the problem using the Backtracking search algorithm, selecting unassigned variables in alphabetical order and iterating over values in numerical order. What is the final solution?

**(3)** Assume we first assign $D = 0$ and then enforce arc-consistency (using a BFS-based propagation that rechecks neighbors when a domain loses a value). What are the remaining values in the domains of each variable after this process?

**(4)** Consider using the Minimum Remaining Values (MRV) heuristic for variable selection (if multiple variables have the same remaining values, follow alphabetical order). After assigning each variable, enforce arc-consistency. What is the final solution?

**Problem 3** (10 points)

Please examine the following Sudoku puzzle and answer the questions.




**(1)** Given the variables A, B, C, D, and E, formulate this problem as a CSP. Describe the domains and constraints.

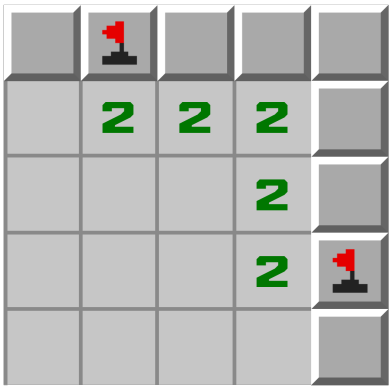
**(2)** Draw the constraint graph for the variables associated with your CSP.

**(3)** When running one iteration of forward checking, which values will be removed for each variable if we assign 2 to A? Write down "None" if no values will be removed.

**(4)** Run the basic backtracking search. Use alphabetical order to both select unassigned variables and iterate over values. Write down the digits assignment for A, B, C, D, and E.

**Problem 4** (10 points)

Consider a Minesweeper game in which the board shows the following observation. On the displayed board, each numbered cell (here, "2") indicates that exactly two mines are hidden among the 8-neighbors (horizontally, vertically, and diagonally) of that cell. Each cell contains at most one mine. The flag placed on the cell indicates that there is a mine.




**(1)** Formulate this puzzle as a CSP. Use the variables $X_{ij}$ where $i$ and $j$ denote the row and column indices, respectively, with the indices starting from 1 and increasing left-to-right and top-to-bottom. Detail the domain of values for each variable and constraints.

**(2)** Suppose an oracle reveals that the upper-left corner $X_{11}$ contains a mine. After applying forward checking and constraint propagation (repeatedly checking consistency until no value can be removed), which variables have only one remaining possible value? What are these values?

**(3)** Based solely on the CSP formulated in part (1) (i.e., without oracle hints), suppose we choose a value of $k$ to perform a k-consistency check. The goal is to determine which cell(s), if any, can be definitively confirmed as safe or containing a mine. If at least one cell can be confirmed, specify it. If no cell can be confirmed, answer "None" and briefly justify your answer using the constraints from part (1). Additionally, if you make a confirmation, determine the minimal value of $k$ required for that confirmation.