### ***Course: CS420 - Artificial Intelligence***

### ***Class 20CTT – Term I/2022-2023***

ONLINE EXERCISE

Note: red color is for teacher’s comments

**Question 01.** *The three couples problem.* Three couples are on a safari, when they come to a river. The only way for them to cross is with a small rowboat which can only accommodate two people at a time. Complicating the process is the fact that the women are all the jealous type, and refuse to leave their significant other in the presence of another woman unless she is there as well. How can the couples cross the river without any romantic strife?

Consider a state as a tuple of values. Which values should be included in the tuple?

| **Represent the women by W, men by M, rowboat by R**  **Couple C1(W1,M1); C2(W2,M2); C3(W3,M3)**  **Each state can be represented by the items on each side**  **Example: Side1{W1,W2,W3,M1}, Side2{M2,M3,R}.**  **Using W for all three wives (and M for husbands) is insufficient to distinguish couples.** |
| --- |

From this point, answer the following questions according to the definition of a state above.

Define the initial state and the goal state.

| **Initial state: Side1{M1,M2,M3,W1,W2,W3,R}, Side2{}**  **Goal state: Side1{}, Side2{M1,M2,M3,W1,W2,W3,R}** |
| --- |

What is the step cost?

| Step cost = 1 |
| --- |
|  |

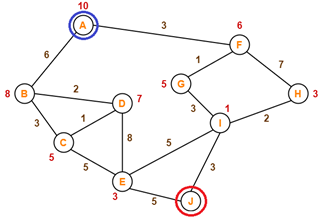
What is the maximum number of states in the state space, i.e., including illegal states? Explain.

| **2^7 , 7 factor in tuple** |
| --- |

What is the total number of reachable states? Explain.

| **This question is temporarily skipped because listing all the states may take time.** |
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**Question 02.** Consider the following graph. The initial state is marked with a BLUE circle, and the goal state is marked with a RED circle. Ties are broken in alphabetical order.

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For each of the following search strategies, state the order in which states are expanded and the path returned. Vertices should be presented in their exact order, and they are separated by a single space, (e.g., S A B C)

Note that the path returned will not be accepted if the list of expanded states is wrong.

Breadth-first search

List of expanded states: A B F C D G H E Path returned: A B C E J

Uniform cost search:

List of expanded states: A F G B I D C H J Path returned: A F G I J

Depth-first search:

List of expanded states: A B C D E Path returned: A B C D E J

Greedy best-first search:

List of expanded states: A F H I J Path returned: A F H I J

Graph-search A\*:

List of expanded states: A F G I J Path returned: A F G I J

| **Question 03.** Consider the 4-bishops problem. Every state of the problem has 4 bishops on the board, each of which is in a separate column.  Answer the following questions: |  |
| --- | --- |

The total number of states in the state space is:

| 4 ^ 4 = 256 |
| --- |

Each step of the search moves a bishop within its own column. How many successors can a state generate?

| 3 \* 4 = 12 |
| --- |

Each state of the problem can be represented in the genetic algorithm as 4 digits, each indicating the position of a bishop in that column. For example, S = 4213.

Let **nb** be the number of attacking pairs of bishops of state n.

Define the fitness function for a state n:

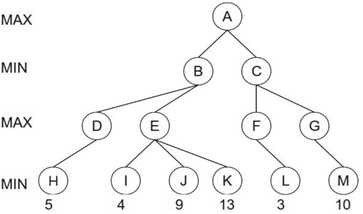
| **Fit(n) = 6 - n** |
| --- |

The current generation includes 4 states: S1 = 2341; S2 = 2132; S3 = 1232; S4 = 4321.

Calculate the value of Fit(n) for each of the 4 states and the probability that each of them will be chosen in the “selection” step.

| State n | S1 | S2 | S3 | S4 |
| --- | --- | --- | --- | --- |
| Fit(n) | **2** | **4** | **2** | **0** |
| Prob(n) | **0.25** | 0.5 | 0.25 | 0 |

**Question 04.** Consider the following game tree. Assume that the root node corresponds to the MAX player and the search always visits children left-to-right.



Compute the final backed-up computed by minimax algorithm. (No alpha-beta pruning at this step)

| A | B | C | D | E | F | G |
| --- | --- | --- | --- | --- | --- | --- |
| 5 | 5 | 3 | 5 | 13 | 3 | 10 |

Compute the final backed-up computed by alpha-beta pruning. If a node is pruned, mark X.

| A | B | C | D | E | F | G |
| --- | --- | --- | --- | --- | --- | --- |
| 5 | 5 | 3 | 5 | 9 | 3 | X |

Using the minimax calculations from part a), without performing any alpha-beta calculation, rotate the children of each node in the above tree at every level to ensure maximum alpha-beta pruning. Fill in the nodes with the letter of the corresponding node. Draw the new edges

|  |
| --- |

**Question 05.** *The 8-puzzle problem*. Apply the hill-climbing algorithm with Manhattan distance heuristic to find a solution for the following pair of initial and goal states.

| Initial state  2 8 3  1 6 4  7 - 5 | Goal state  1 2 3  8 - 4  7 6 5 |
| --- | --- |

Your work should address the following requirements

- Draw the search tree including all possible successors of expanded states (except the goal)

- Calculate the heuristic value for every node

- Mark the optimal strategy found

| **Question 06.** Consider the problem of coloring the six regions (numbered 1...6) in the following map using three colors: R, G and B, so that no adjacent regions have the same color. Two regions are adjacent if they share part of an edge (note: they are NOT adjacent if they only share a corner). |  |
| --- | --- |

If initially every variable has all three possible values except region 1 has known value R (1 = R) and region 2 has known value G (2 = G). What is the result of the Forward Checking algorithm for this step?

| Variables | 1 | 2 | 3 | 4 | 5 | 6 |
| --- | --- | --- | --- | --- | --- | --- |
| Final domains | **R** | **G** | G,B | O,B | R,B | B,O |

Assume the initial domains of the regions in the map above are given as 1 = {R, G, B}, 2 = {R, G}, 3 = {R, G, B}, 4 = {R}, 5 = {R, G, B}, and 6 = {R}. What is the result of applying the Arc Consistency algorithm, AC-3, starting at Region 1?

| Variables | 1 | 2 | 3 | 4 | 5 | 6 |
| --- | --- | --- | --- | --- | --- | --- |
| Final domains | G, B | G | G, B | {} (4-6) | R, G, B | R |

Assume no variables have been assigned yet, solve the CSP using backtracking with forward checking. Ties (after considering all necessary heuristics) are resolved by numeric ordering (e.g., if both region 1 and region 2 are possible, choose region 1).

For every step, present the *MRV values for all regions that are not colored yet*. If there are many *regions that have the same minimum MRV*, present the DH values for these regions.

Step 1

| Variables | 1 | 2 | 3 | 4 | 5 | 6 |
| --- | --- | --- | --- | --- | --- | --- |
| MRV | 3 | 3 | 3 | 3 | 3 | 3 |
| DH | 3 | 3 | 2 | 3 | 2 | 3 |

Color the region \_\_\_\_\_\_\_\_\_\_1\_\_\_\_\_\_\_\_\_\_ with the color \_\_\_\_\_\_\_R\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Step 2

| Variables | 1 | 2 | 3 | 4 | 5 | 6 |
| --- | --- | --- | --- | --- | --- | --- |
| MRV |  | 3 | 2 | 2 | 3 | 2 |
| DH |  | 3 | 1 | 2 | 2 | 2 |

Color the region \_\_\_\_\_\_\_\_\_\_\_\_\_4\_\_\_\_\_\_\_\_\_\_ with the color \_\_\_\_\_\_\_\_\_\_\_G\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Step 3

| Variables | 1 | 2 | 3 | 4 | 5 | 6 |
| --- | --- | --- | --- | --- | --- | --- |
| MRV |  | 2 | 2 |  | 3 | 1 |
| DH |  |  |  |  |  |  |

Color the region \_\_\_\_\_\_\_\_\_ 6\_\_\_\_\_\_\_\_\_\_\_\_ with the color \_\_\_\_\_\_\_\_\_\_\_\_B\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Step 4

| Variables | 1 | 2 | 3 | 4 | 5 | 6 |
| --- | --- | --- | --- | --- | --- | --- |
| MRV |  | 1 | 2 |  | 3 |  |
| DH |  |  |  |  |  |  |

Color the region \_\_\_\_\_\_\_\_2\_\_\_\_\_\_\_\_\_\_\_\_ with the color \_\_\_\_\_\_\_\_\_\_R\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Step 5

| Variables | 1 | 2 | 3 | 4 | 5 | 6 |
| --- | --- | --- | --- | --- | --- | --- |
| MRV |  |  | 2 |  | 2 |  |
| DH |  |  |  |  |  |  |

Color the region \_\_\_\_\_\_\_\_\_\_\_\_ 3\_\_\_\_\_\_\_\_\_\_\_\_\_ with the color \_\_\_\_\_\_\_\_\_\_G\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Step 6

Color the region \_\_\_\_\_\_\_\_\_\_\_\_\_\_ 5 \_\_\_\_\_\_\_\_\_\_\_\_\_ with the color \_\_\_\_\_\_\_\_\_\_ B\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_