King Saud University	College of Computer and Information Sciences Department of Computer Science
CSC 361: Artificial intelligence	**Midterm exam - Spring 2021**
Date: 21/03/2021	Duration: 90 minutes

Student ID:	Name:
Sequential number:	Section/Instructor:

Question	Points	Score
Problem formulation-Search problems	20	
Search algorithms	30	
Problem formulation-Local Search	15	
Adversarial search	15	
CSP	20	
Total:	100	

Question 1: Problem formulation-Search problems....................................20 points

An agent is given a path of N white, black and red cells. An example of such a path is shown in Figure 1. The agent starts on the leftmost cell and the goal is to move to the right end of the path in minimum number of moves.The exact configuration of the white, black and red cells and the length of the path vary with the instance of the problem the agent is given to solve.

If the agent is on a white cell, he can move 1 or 2 cells to the right. If the agent is on a black square, he can move 1 or 4 cells to the right. If the agent is on a red cell, he must move to the starting position (the leftmost cell).

For the following questions, you should answer for a general instance of the problem, not simply for the example shown in the figure.

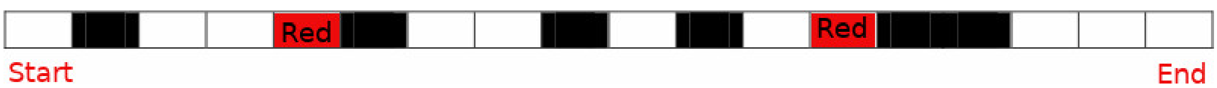


Figure 1: A path of of white, black and red cells (N=18 cells)

1. The **minimal** state representation is: (3 points)

   (A) The position of the agent (from 1 to N).

   (B) The color of the cell in which the agent is.

   (C) A 1D array of size N representing the color of each cell in the path.

   (D) The list of cells that have not been visited.

2. Select **all** the actions that can be performed: (3 points)

   (A) Move to the start position of the path if the current cell is red.

   (B) Move to the black cell.

   (C) Move one cell to the right.

   (D) Move 4 cells to the right if the current cell is black.

   (E) Move to the white cell.

   (F) Avoid the red cell.

   (G) Move 2 cells to the right if the current cell is white.

   (H) Move to the red cell.

3. What is the goal state: (3 points)

   (A) Move to the right end of the path in the minimum number of moves

   (B) The position of the agent is the N^{th} cell at the right end of the path.

   (C) Avoid red cells

   (D) None of the above

4. The cost of an action is: (3 points)

   (A) 0

   (B) 1

   (C) The number of cells the agent has jumped.

   (D) None of the above

5. What is the maximum branching factor: (3 points)

   (A) 2 (B) 4

   (C) 1 (D) None of the above

6. Select the heuristics that are admissible: (5 points)

   (A) One for any state.

   (B) The number of cells remaining to reach the right end of the path.

   (C) The number of cells remaining to reach the right end of the path divided by 4.

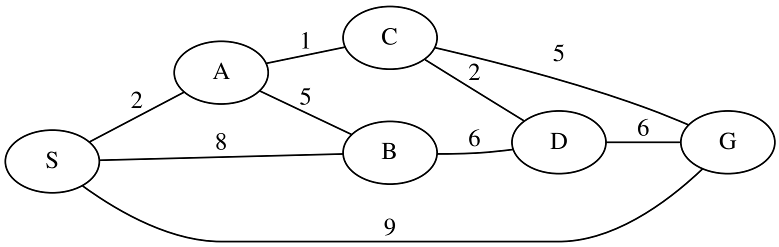
   (D) The number of cells remaining to reach the right end of the path divided by 2.

   (E) The minimum between the number of the remaining white cells and the remaining black cells to reach the right end of the path.

Question 2: Search algorithms..30 points

(a) **Uninformed search**

Consider the following state space graph, where S is the start state and G is the goal state. The cost for each edge is shown on the graph. **All ties are broken alphabetically. Nodes are expanded in alphabetical order.**



1. **After performing BFS graph search:** (each one 1.5 points)
   (a) What is the obtained solution:
   - (A) S-A-C-D-G
   - (B) S-A-C-G
   - (C) S-A-B-D-G
   - **(D) None of the above**

   (b) What is the cost of the obtained solution:
   - (A) 8
   - **(B) 9**
   - (C) 11
   - (D) None of the above

   (c) What is the content of the explored set:
   - (A) S-A-C-D-B
   - (B) S-A-B-D
   - **(C) S**
   - (D) None of the above

   (d) What is the content of the Frontier when the search stops:
   - (A) B
   - **(B) A-B**
   - (C) Empty
   - (D) None of the above

2. **After performing UCS graph search:** (each one 2 points)
   (a) What is the obtained solution:
   - (A) S-A-C-D-G
   - **(B) S-A-C-G**
   - (C) S-A-B-D-G
   - (D) None of the above

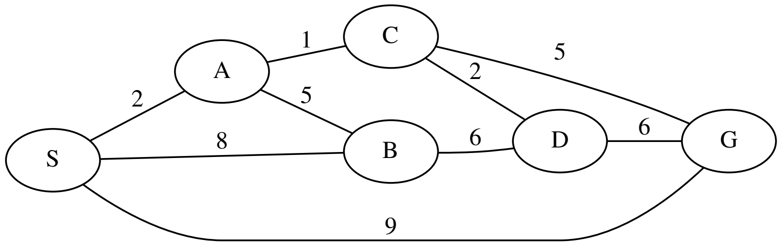
   (b) What is the cost of the obtained solution:
   - **(A) 8**
   - (B) 9
   - (C) 11
   - (D) None of the above

   (c) What is the content of the explored set:
   - **(A) S-A-C-D-B**
   - (B) S-A-B-D
   - (C) S
   - (D) None of the above

   (d) What is the content of the Frontier when the search stops:
   - (A) B
   - (B) A-B
   - **(C) Empty**
   - (D) None of the above

(b) **Informed search**

Consider the following graph, where S is the start state and G is the goal state, and the heuristic is shown in the table:



state n	h(n)
S	4
A	2
B	6
C	3
D	3
G	0

1. After performing **Greedy** graph search (**nodes are expanded in alphabetical order**): (each one 2 points)

   (a) What is the obtained solution:
   - (A) S-A-C-D-G
   - (B) S-A-C-G
   - (C) S-A-B-D-G
   - **(D) None of the above**

   (b) What is the cost of the obtained solution:
   - (A) 8
   - **(B) 9**
   - (C) 11
   - (D) None of the above

   (c) What is the content of the explored set:
   - (A) S-A-C-D-B
   - (B) S-A-B-D
   - **(C) S**
   - (D) None of the above

   (d) What is the content of the Frontier when the search stops:
   - (A) B
   - **(B) A-B**
   - (C) Empty
   - (D) None of the above

2. After performing **A*** graph search (**nodes are expanded in alphabetical order**): (each one 2 points)

   (a) What is the obtained solution:
   - (A) S-A-C-D-G
   - **(B) S-A-C-G**
   - (C) S-A-B-D-G
   - (D) None of the above

   (b) What is the cost of the obtained solution:
   - **(A) 8**
   - (B) 9
   - (C) 11
   - (D) None of the above

   (c) What is the content of the explored set:
   - (A) S-A-C-D-B
   - (B) S-A-B-D
   - (C) S
   - **(D) None of the above**

   (d) What is the content of the Frontier when the search stops:
   - **(A) B**
   - (B) A-B
   - (C) Empty
   - (D) None of the above

Question 3: Problem formulation-Local Search .... 15 points

A building floor can be represented by an $n \times n$ 2D grid with obstacles. We want to position K air-conditioners in this building so that the Manhattan distance between any two air-conditioners is larger or equal to a specified threshold $T > 0$. The air-conditioners cannot be placed in cells having an obstacle (black cells). The Manhattan distance between two positions $p1 = (x_1, y_1)$ and $p2 = (x_2, y_2)$ is defined as $d(p1, p2) = |x_2 - x_1| + |y_2 - y_1|$.

Figure 2 shows a grid with $n = 3$, $K = 3$, and the distance between any two air-conditioners is greater or equal to $T = 2$.

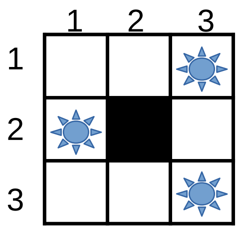


Figure 2: Example grid

Give a local search formulation of this problem (the formulation must be general and not for the example above only):

1. A **minimal** state representation is: (4 points)
   - **(A) The positions of the air-conditioners on the grid.**
   - (B) A 2D grid with the air-conditioners and the position of the obstacles.
   - (C) The distances between the air-conditioners.
   - (D) One cell of the grid.
2. The actions: (4 points. I have considered the option B correct if you selected the option A in the next question.)
   - (A) Move all the air-conditioners to new empty positions.
   - (B) Add an air-conditioner to an empty place or remove one air-conditioner.
   - (C) Add an air-conditioner to an empty place.
   - **(D) Move one air-conditioner to a new position that is empty.**
3. The initial state: (4 points)
   - (A) A grid without air-conditioners.
   - (B) Randomly assigned values to the distances between the air-conditioners.
   - (C) A randomly chosen cell from the grid.
   - **(D) All air-conditioners, randomly assigned to positions on the grid.**
4. The objective function: (3 points)
   - (A) The average distance between all the air-conditioners.
   - (B) The sum of all distances.

(C) The Manhattan distance between any two air-conditioners is larger or equal to a specified threshold $T > 0$.

(D) The number of pairs of air-conditioners that are separated by a distance that is less than the threshold T.

Question 4: Adversarial search .... 15 points

After applying Alpha-Beta pruning to the tree in Figure 1. Show the **final** obtained value at each node and the **final** values of α and β at each node.

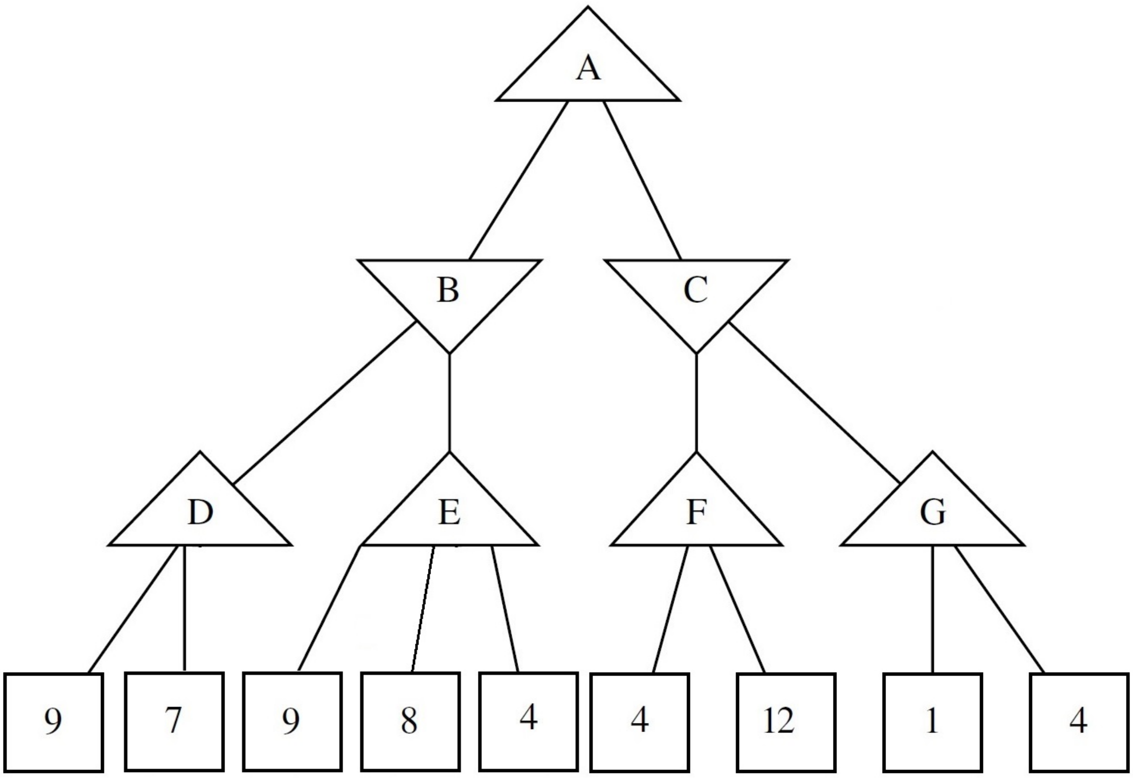


Figure 3: Game tree

1. At node **A**, Alpha-Beta pruning returns: (1 points)
   - (A) 9 for this node, $\alpha = +\infty$ and $\beta = 9$.
   - (B) 8 for this node, $\alpha = +\infty$ and $\beta = 8$.
   - **(C) 9 for this node, $\alpha = 9$ and $\beta = +\infty$.**
   - (D) None of the above.
2. At node **B**, Alpha-Beta pruning returns: (2 points)
   - (A) 9 for this node, $\alpha = +\infty$ and $\beta = 9$.
   - (B) 8 for this node, $\alpha = -\infty$ and $\beta = 8$.
   - **(C) 9 for this node, $\alpha = -\infty$ and $\beta = 9$.**
   - (D) None of the above.
3. At node **D**, Alpha-Beta pruning returns: (2 points)
   - (A) 7 for this node, $\alpha = 7$ and $\beta = +\infty$.
   - **(B) 9 for this node, $\alpha = 9$ and $\beta = +\infty$.**
   - (C) 9 for this node, $\alpha = +\infty$ and $\beta = 9$.
   - (D) None of the above.
4. At node **E**, Alpha-Beta pruning returns: (2 points)
   - (A) 9 for this node, $\alpha = -\infty$ and $\beta = 9$.
   - (B) 8 for this node, $\alpha = -\infty$ and $\beta = 8$.
   - (C) 9 for this node, $\alpha = 9$ and $\beta = +\infty$.
   - **(D) None of the above.**

5. At node **C**, Alpha-Beta pruning returns: (2 points)

   Ⓐ 4 for this node, $\alpha = 9$ and $\beta = 12$.

   Ⓑ 4 for this node, $\alpha = 9$ and $\beta = 4$.

   Ⓒ This node is pruned (it has not been checked).

   Ⓓ None of the above.

6. At node **F**, Alpha-Beta pruning returns: (2 points)

   Ⓐ 12 for this node, $\alpha = 9$ and $\beta = 12$.

   Ⓑ 12 for this node, $\alpha = 12$ and $\beta = +\infty$.

   Ⓒ This node is pruned (it has not been checked).

   Ⓓ None of the above.

7. At node **G**, Alpha-Beta pruning returns: (2 points)

   Ⓐ 4 for this node, $\alpha = 9$ and $\beta = 12$.

   Ⓑ 4 for this node, $\alpha = 4$ and $\beta = 12$.

   Ⓒ This node is pruned (it has not been checked).

   Ⓓ None of the above.

8. The links that have been pruned are: (2 points)

   Ⓐ Link (E,8) and (E,4).

   Ⓑ Link (F,12).

   Ⓒ Link (E,8) and (C,G).

   Ⓓ None of the above.

Question 5: CSP .... 20 points

A student uses CSP to solve the following problem.

The student is asked to write the numbers 1 to 7 in the cells $\{C1, C2, C3, C4, C5, C6, C7\}$ of Figure 4. There is only one number allowed in every cell. Two consecutive numbers are not allowed to be in adjacent fields (example: if $C1 = 1$, $C2$ and $C3$ cannot take 2). Two fields are adjacent if they have one edge in common (example: $C1$ is adjacent to $C2$) or one corner in common (example: $C1$ is adjacent to $C3$).

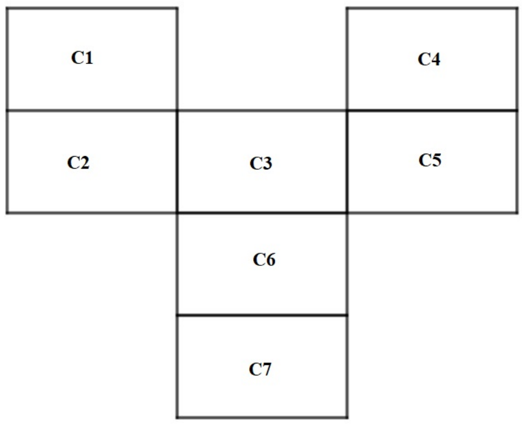


Figure 4: Puzzle

Select all the statements that are correct: (each statement 2 points)

Ⓐ The variables of the given problem are $\{C1, C2, C3, C4, C5, C6, C7\}$.

Ⓑ The domain of $C2$ is $\{3, 4, 5, 6, 7\}$.

Ⓒ The constraint graph representing only the binary constraints has 10 edges.

Ⓓ Backtracking search must assign values to $\{C1, C2, C3, C4, C5, C6, C7\}$ in this order.

Ⓔ Backtracking search must assign 1 to $C1$ since it starts with C1.

Ⓕ The given problem has the following constraint $C1 \neq C2 \neq C3 \neq C4 \neq C5 \neq C6 \neq C7$.

Ⓖ The given problem has the following constraint $|C3 - C5| > 1$.

Ⓗ After assigning 1 to $C1$, Forward Checking removes 1 from the domain of all the other variables

and removes 2 from the domain of $C2$ and $C3$.

Ⓘ The given problem has the following constraint $C6 = C5 + 2$.

Ⓙ Forward Checking can be applied as a preprocessing step before applying backtracking search.