COMP 424 Winter 2018 - Assignment 2

Due Date: Feb 18, 2019, 9:00pm on myCourses

General instructions:

- This is an individual assignment. You can discuss solutions with your classmates, but should only exchange information orally, or else if in writing through the discussion board on myCourses. All other forms of written exchange are prohibited.
- Unless otherwise mentioned, the only sources you should need to answer these questions are your course notes, the textbook, and the links provided. Any other source used should be acknowledged with proper referencing style in your submitted solution.
- Submit **a single pdf document** containing all your pages of your written solution on your McGill's myCourses account. You can scan-in handwritten pages. If necessary, learn how to combine many pdf files into one.

1 Searching under uncertainty

Oh no, one of your friends, Grasshopper, is trapped in a tunnel system and is in mortal danger! You and three other friends have to help him. You have at your disposal a map of the tunnel system indicating also where Grasshopper (marked with a 'G') is located.

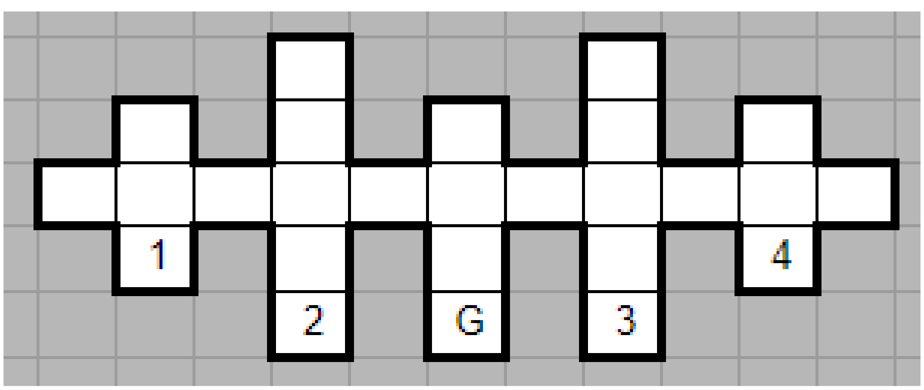

Figure 1: Map of tunnel system. Thick lines represent walls and white spaces are tunnel spaces in which you can travel.

To access the tunnel, each of you and your three friends are teleported to one of the 4 entrances marked on the map (marked as 1-4). You will each be teleported to different entrances (no two friends will appear in the same entrance). Because the tunnel system is very dark, you cannot see past what is beyond the tile you are in.

1. Assuming that each of you and your friends' initial beliefs consists of all states (not just the entrances), what is the total number of possible beliefs of any one of you in this domain? You don't have to care about where your friends are.

2. The walls that may enclose a given tile can be perceived by you or your friends (ex. Grasshopper is trapped in a dead-end with walls on the east/west/south sides). How many **distinct** percepts are possible in this domain? Are there any unique percepts (landmarks) that can be used to indicate where you are in the map? If there are, indicate them. You can use a coordinate system where the bottom-left most point is the origin (e.g. location of entrance 2 is at (4,1)).

3. Grasshopper will suffocate if you don't save him in time! He is saved if any 2 of you reach G in strictly less than 60 minutes. You now begin with each of you teleported to your respective entrance (without knowing which entrance you have been teleported to!)

   There are 4 actions you can take at each tile: walking northwards, southwards, eastwards, or westwards. Each of these actions will move you to the tile in that direction costing you 5 minutes, even if you run into a wall.

   Is there a conformant plan that can save Hopper in time? If so share it. If not explain why. You can use $(\Rightarrow N)^2 \Rightarrow S$ to mean the sequence of actions {"Moves North" , "Moves North" ,"Moves South"}.

2 Game playing

Consider the following game, consisting of a set of boxes coloured either red or blue. You are allowed to place red boxes while your adversary places blue boxes, and you each take turns placing. If there are ever three boxes of the same colour that form a column or a row, you lose!

2.1 Summary

1. Board is a 3x3 grid with the initial state shown in Fig 2; it is your turn

2. You are responsible for placing red boxes

3. The adversary places blue boxes

4. You lose if either Red or Blue forms:

   - A row

- A column

5. You win if board fills up
6. Good Luck!

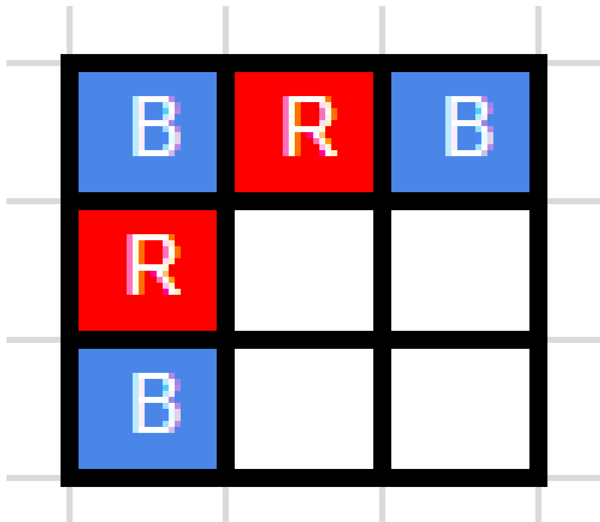

Figure 2: Current state of boxes. R represents red boxes and B represents blue boxes

1. Draw the search graph consisting of all possible game states (starting from the current state), with the orientation of the board fixed as in the figure above. For the remaining questions you can use the graph to show the algorithms.
2. Apply the minimax algorithm to find the best course of action. Can you guarantee a win? If so, show how the game would play out.
3. Apply alpha-beta pruning to the search tree by going down the branch where the first move of Red is on the tile on the second row, third column. Show your work to demonstrate which sub-trees are pruned.

3 Propositional Logic

1. How many models are there that satisfy each of the following?
   (a) $(A \land B) \lor C$
   (b) $A \land (A \Rightarrow B) \land \neg B$
   (c) $\neg (A \land B \land C \land D \land E \land F) \lor (B \land C)$

2. State whether each of the following sentences is Valid, Unsatisfiable, or Satisfiable. Support each of your answers using a truth table or a logical inference.

   (a) $((A \Rightarrow B) \wedge (A \vee C)) \Rightarrow (B \vee C)$

   (b) $((A \vee B) \Rightarrow C) \Rightarrow ((A \Rightarrow C) \wedge (B \Rightarrow C))$

   (c) $\text{False} \Rightarrow A \vee B \vee C \vee D \vee \neg A$

   (d) $\text{True} \Rightarrow ((A \vee B) \wedge \neg A \wedge \neg B)$

4 First Order Logic

Dustey, Elody, and Michael joined William at the local snack shop. Each of them bought at least one of 3 snacks: eggo, chocolate pudding, or 3-musketeers. Those who bought pudding did not buy eggos and those who bought 3-musketeers also bought pudding. Elody is mad at Michael, so out of the 3 snacks she bought everything that Michael did not buy. Michael and Dustey bought a bar of 3-musketeers.
For the following questions use Bought(x,y) to mean x bought y.

1. Define the relevant predicates and translate the facts listed above into first-order logic. Clearly distinguish between variables and constants in each formula.

2. Convert all facts from part 1 to CNF. Number each of the clauses.

3. Query: Did any of them only buy eggos?
   Answer the query by using proof by resolution or explain why not. Use the numbers from part 2 for your proof/explanation.

   Hint: To show $A \vee B$ is false show that both A is false and B is false

5 Constraint Satisfaction

Consider the problem of placing 2 knights and 2 queens on a 4 x 4 chessboard, each piece (knight or queen) per row (denoted by $R1$, $R2$, $R3$, and $R4$) as shown in the figure, such that no two pieces are attacking each other. One knight must be placed in row $R1$, the other in $R2$, one queen in $R3$, and the other queen in $R4$.

1. Formulate this problem as a Constraint Satisfaction problem. Describe the set of variables, and their domain. List the set of constraints. Draw the constraint graph.

2. Show the search tree generated when applying backtracking search, without forward checking for the problem. Show clearly the domain for each variable at every point in the search.

3. Show the search tree generated by applying the forward checking strategy.

4. Repeat the above questions for the same problem but with 1 knight, 1 bishop, 1 rook, and 1 queen that are allowed to be placed anywhere on the 4x4 chessboard.

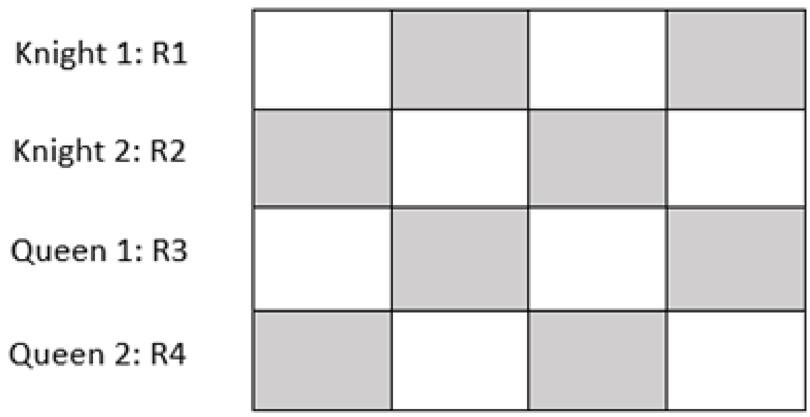

Figure 3: The chessboard for the constraint problem described in 5.1, where the rows are denoted by R1, R2, R3, and R4, and the first knight is allowed to be placed on R1, the second knight on R2, the first queen on R3, and the second queen on R4.