COMP-424: Artificial intelligence, Winter 2022

Homework 2

Due on *myCourses* Tuesday Feb 22, 9:00pm.

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 *Ed*. 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.
- For each problem, you can solve manually, or write a program to help you. You can use a programming language of your choice. You can modify code from other sources if you provide adequate citation; this cannot be code from other students in the class.
- Submit a single pdf document containing all your pages of your written solution on your McGill's *myCourses* account. You can scan-in hand-written pages. If necessary, learn how to combine many pdf files into one.
- Submit any code developed to answer questions as a separate file to McGill's *myCourses*.

Question 1: Constraint satisfaction [25]

Consider the following problem:

You want to solve a simplified 4x4 version of the Sudoku game with the following grid configuration:

			4
			2
1		4	
			1

Each row, column and 2x2 square rooted in one of the 4 corners should contain the digits "1", "2", "3", "4" exactly once.

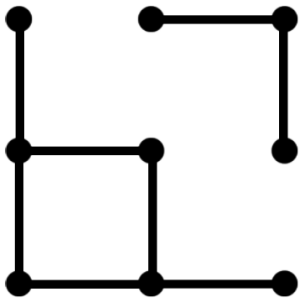
a) Formulate this problem as a CSP. List the variables, their domains, and the constraints. Draw the constraint graph.

b) Show the first ten steps of backtracking search on this problem, where you order the variables in increasing order first by row, then by column, and the values from lowest to highest. Recall that backtracking search uses a depth-first strategy to expand the search tree.

c) Show the first ten steps of backtracking search on this problem **with one-step forward checking**, where you order the variables in increasing order first by row, then by column, and the values from lowest to highest.

Question 2: Search and Game Playing [30]

You are playing the dots and boxes game on a 3x3 grid shown below. Each player has to draw an edge connecting two dots, if it doesn't already exist. The player who draws the 4th line making a unit square receives a +1 score. The player with the largest score after none of the players can draw edges anymore wins the game.



It's the max player's turn.

a) Apply the Minimax algorithm to the above state, by preferring horizontal moves to vertical moves, and expanding in increasing order first by row, then by column. For convenience, you can represent the moves as (start row, start column, end row , end column), e.g. drawing a vertical line in the bottom right corner can be represented as the move (3, 3, 2, 3) or equivalently (2, 3, 3, 3). Draw the corresponding search tree.

b) Apply the alpha-beta pruning method using the same order of node expansion and show the alpha-beta values for all nodes. Is there any advantage to using alpha-beta pruning?

Question 3: Propositional Logic [20]

a) How many models are there for each of the following statements in propositional logic?
   i) $\neg(A \wedge B) \vee \neg(C \wedge \neg B)$
   ii) $A \Rightarrow (A \wedge B) \wedge \neg B \vee \neg C$
   iii) $\neg(A \Rightarrow B \wedge C \wedge D) \vee (B \Rightarrow \neg C)$

b) State whether each of the following is valid, unsatisfiable, or satisfiable. Support your answers with a truth table or a proof using rules of logical inference.
   i) $((A \vee B) \Rightarrow C) \Rightarrow (A \Rightarrow C) \wedge (B \Rightarrow C)$
   ii) $((A \Rightarrow B) \wedge (A \vee C)) \Rightarrow (B \vee C)$

Question 4: First Order Logic [30]

Consider a vocabulary with the following symbols:

Occupation(p, o): Predicate. Person p has occupation o
Customer(p1, p2): Predicate. Person p1 is a customer of person p2.
Boss(p1, p2): Predicate. Person p1 is a boss of person p2.
Doctor, Surgeon, Lawyer, Actor: Constants denoting occupations.
Emily, Joe: Constants denoting people.

a) Use these symbols to write the following assertions in FOL:
   i) Emily is either a surgeon or a lawyer.
   ii) Joe is an actor, but he also holds another job.
   iii) All surgeons are doctors.
   iv) Joe does not have a lawyer.
   v) Emily has a boss who is a lawyer
   vi) There exists a lawyer all of whose customers are doctors.
   vii) Every surgeon has a lawyer.

b) Give a model of the above FOL such that clauses i) – vii) above are satisfied.